area. The highest generalized value of 175 in. (4445 mm) allows for the sizeable areas well below 4,000 ft (1,220 m) that cover much of this region.

The generalized highest isohyetal value of 175 in. (4445 mm), determined from the aforementioned basins, was applied throughout the region of similar overall topography both between and beyond these basins.

c. The region around Juneau is one of rather dense data coverage (low-elevation rain gages plus considerable streamflow measurements). However, this is also a region of pronounced changes in orography in rather small distances. Small areas in and around Carlson Creek and Gold Creek are snow-covered or glaciated even though the highest elevations are barely 4,000 ft (1,220 m) or slightly higher. This suggests (by fig. 13) a MAP of 200 in. (5080 mm) or higher for these areas. The generalized MAP lines over these and adjoining basins are drawn so that we allow for two other factors. These are: (1) the low-elevation precipitation measurements nearby and (2) the fact that portions of Carlson Creek, Gold Creek, and nearby basins are below 1,000 ft (305 m). A generalized MAP isoline must be representative of the average elevation that it encompasses (sec. 2.2.1).

d. An area void of conventional precipitation and also runoff data is the area around the Chilkat range -- the main close-in barrier to the west of the Juneau area. Here, on the basis of figure 13, we build up the MAP to a generalized value of 175 in. (4445 mm). Elevations of 4,000 ft (1,220 m) or a little higher are generally required for limited glaciation in this region. Occasionally, small glaciers appear at elevations below 4,000 ft (1,220 m). However, we judge a rather sizeable 175-in. (4445-mm) isohyet adequate for this mountain range since it encompasses quite a large area that goes below 1,000 ft (305 m).

e. On Admiralty Island (near 57.75°N, 134.50°W), a small 150-in (3810-mm) isohyet is inserted to make some allowance for isolated areas of near 200 in. (5080 mm) to account for the small glaciers around 4,000 ft (1,220 m) in this area. The predominance of elevations below 2,000 to 3,000 ft (610 to 915 m) suggests not going any higher than this on a generalized basis.

The five examples just discussed demonstrate how figure 13 was effective in adjusting the first approximation MAP chart on the basis of existence or nonexistence of small glaciers. Although the development of the procedure was rather involved and challenging, reward came in its utility for improving the MAP analysis in mountainous areas that had insufficient alternate data.

2.5 Final Mean Annual Precipitation Chart

Figure 4 shows the final MAP analysis based upon a first approximation from precipitation measurements, streamflow measurements, and generalized topographic considerations and with further adjustments for existence or nonexistence of small glaciers. This MAP chart becomes a key input to development of generalized 24-hr 10-mi^2 PMP (26 km^2) described in chapter 3. Somewhat more detailed orographic considerations are part of the PMP development.

3. PROBABLE MAXIMUM PRECIPITATION FOR SOUTHEAST ALASKA

3.1 Introduction

A generalized study and numerous individual basin estimates of probable maximum precipitation (PMP) have been made for Alaska (sec. 1.1). These estimates have involved a variety of approaches. Frequently, analogies were made in the earlier studies to similar regions in western United States for guidance in maintaining the same general level of PMP in both regions. The analogies were required since the observational network in Alaska is very sparse. Large regions may have only a few stations, and some rather extensive regions lack any data. Even where observations are available, they frequently are not representative of the diverse physiographic regions of Alaska.

PMP estimates made on a generalized basis, that is, mapped values over a region, avoid inconsistencies that could easily result from estimates made at various times for individual basins. The available Alaskan generalized PMP report (Miller, 1963) is for the entire State. In this 1963 generalized study, the relation of PMP to orography came from relations developed for mountains in the western states from California northward.

The present generalized PMP study concentrates on just the southeast portion of Alaska (fig. 1) with a primary aim of providing a greater definition of orographic effects for the restricted area of concern than that provided by the earlier generalized study that covered all of Alaska. Seasonal variation to cover the snowmelt season is also included. Using the MAP chart (fig. 6) for southeast Alaska described in chapter 2 as an index, we developed relations of PMP to MAP from portions of a generalized PMP report for the Northwest States (U.S. Weather Bureau, 1966). We also made use of another technique where 100-yr rainfall values in southeast Alaska were related to MAP and PMP.

Three factors that influenced the approach used in developing generalized estimates for southeast Alaska are:

a. The varied and complicated orographic features of the region,

b. The fact that nearly all the regular precipitation measurements are at low elevations, and

c. The short record length of most precipitation stations and consequently the lack of a large number of stations with long continuous records.

We know from many studies of major storms and PMP in other orographically complicated areas that the orography in southeast Alaska must produce significant effects on precipitation. After reviewing the topography and storm morphology in the western United States, we chose the western portion of the State of Washington as the most appropriate region for development of relations between PMP and MAP that could then be adapted for use in southeast Alaska. Except for points in the Olympic Mountains region* (where orographic effects on precipitation are somewhat more severe than the most orographic portion of the study area), western Washington has many orographic features similar to southeast Alaska. Additionally, large precipitation amounts result from similar storm types.

3.2 Relation Between Probable Maximum Precipitation and Mean Annual Precipitation

3.2.1 Relation from Western Washington

Figure 14 shows the location of points in western Washington for which 24-hr 10-mi^2 (26-km^2) PMP was determined from Hydrometeorological Report No. 43 (U.S. Weather Bureau, 1966). MAP was determined from an analysis prepared by the National Weather Service River Forecast Center, Portland, Oregon (1965). A plot of these data and a fitted linear regression line are shown in figure 15. The linear relation has a correlation coefficient of 0.87 and standard error of estimate of 3.5 in. (90 mm).

3.2.2 Adjustment of Western Washington Relation for Use in Southeast Alaska

Storm morphology is basically the same for the region from western Washington to southeast Alaska. Substantial influx of moisture with rather strong pressure patterns characterize most storms affecting the region. As latitude increases, the average interval between storms decreases. Also, the number of months during which the same basic rain-producing storm type prevails increases as the latitude increases. Both of these effects result in greater MAP with increasing latitude, other things, such as orographic effects, being the same. This does not mean that PMP should necessarily increase with increasing latitude. In other words, for large areas with varying topography, large MAP values with increasing latitude does not, in itself, imply larger PMP.

In addition to the influence of terrain and varying storm frequency, the optimum interplay of storm efficiency and moisture determine the magnitude of PMP. Ideally, one might try to develop a family of relations of PMP versus MAP for a variety of orographic settings each with a similar storm morphology and adjust these for storm frequency. Unfortunately, the requisite information is not available. Therefore, we developed a single relation of MAP versus PMP for western Washington, fully realizing that some of the area (i.e., Olympic Mountain upslopes) has the capability of experiencing greater PMP than the less extensive upslopes of southeast Alaska.

We adjusted the relation based on Washington data for the effect of greater storm frequency on MAP with increasing latitude. We developed the storm-frequency adjustment from the data in "Principal Tracks and Mean Frequencies of

*Numbers 18-33 in figure 14.

Cyclones and Anticyclones in the Northern Hemisphere" (Klein, 1957). We summed the annual frequency of storms in 5° lat.-long. quadrangles along the west coast of North America from California to southeast Alaska. Figure 16 shows the results of this summation expressed as a percent of the number of low centers off the Washington coast (quadrangle C). The 47 percent greater frequency of storms off southeast Alaska is used in adjusting the Washington relation of figure 15 for use in southeast Alaska, i.e., the regression curve is multiplied by the inverse of 147 percent.

The validity of using the frequency of low-pressure centers as an adjustment technique for equating MAP values along the coast rests upon the assumption that the average of individual storm precipitation intensities (as distinguished from orographic effects) does not vary much with latitude. In other words, it is the greater number of days with storms as latitude increases that makes the difference in buildup in MAP with latitude. The similarity of depth-duration precipitation summaries of storms along the west coast supports similar storm characteristics. Apparently what happens is that the somewhat higher winds with increasing latitude in storm situations are counteracted on the average by lessened moisture with latitude to make the average storm precipitation intensity (without orographic effects) about the same.

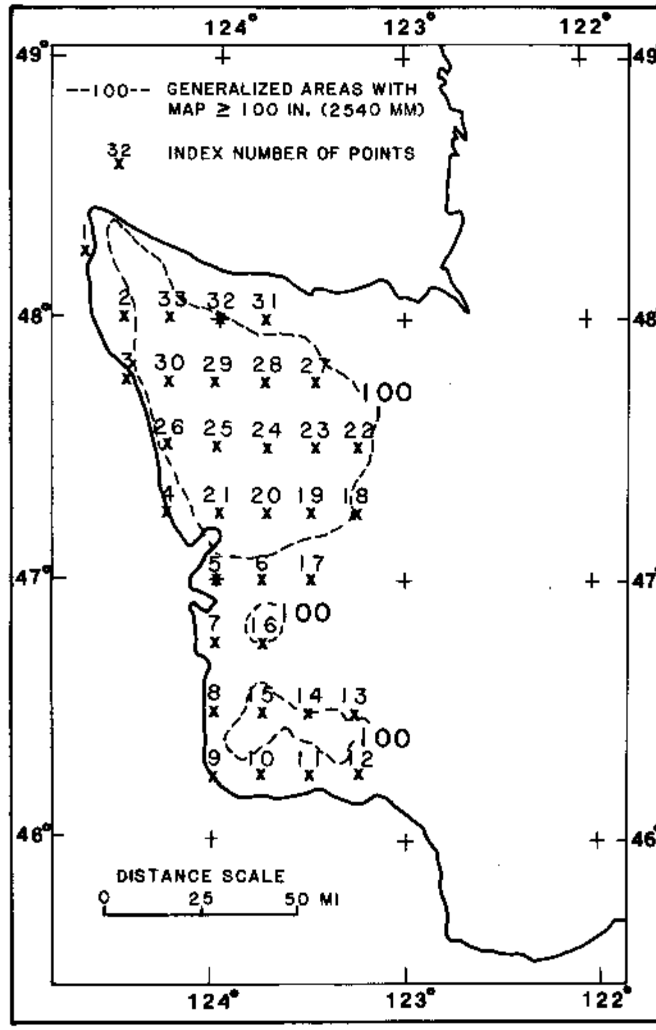


Figure 14.—Location of western Washington points used for probable maximum precipitation vs. mean annual precipitation relation.

The validity of the use of this frequency-adjustment technique also required that the MAP curve comes predominantly from the same overall storm type. For example, if thunderstorms contributed if thunderstorms contributed significantly to the season's precipitation total for only a portion of the region for which such an adjustment is used, we would have to take this into consideration by some adjustment, or otherwise abandon such a technique. Since organized low-pressure systems predominate in most of the precipitation-producing situations along the west coast of North America north of California, we did not have to concern ourselves with this mixed-storm-type problem.

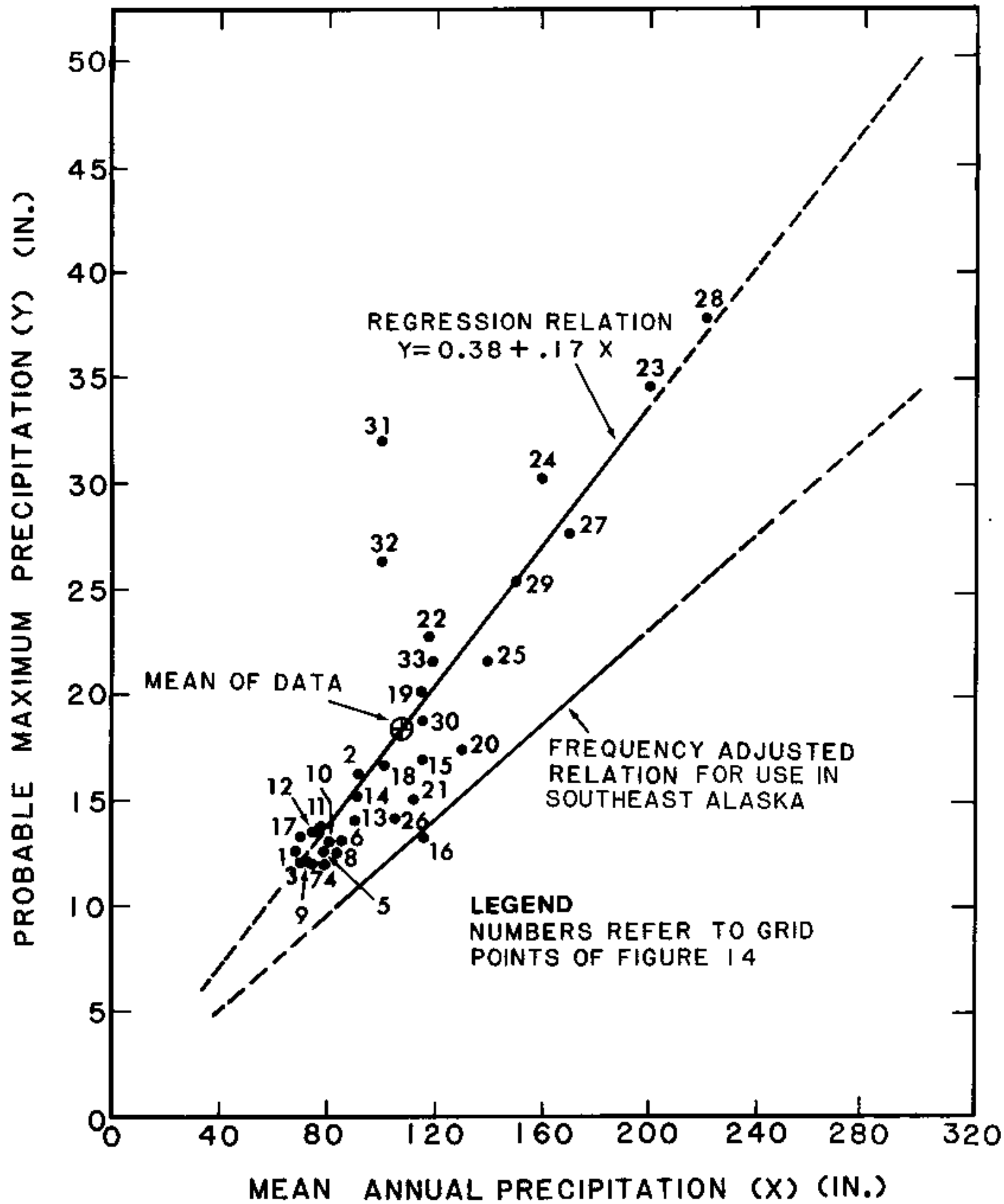


Figure 15.—24-hr 10-mi^2 probable maximum precipitation vs. mean annual precipitation from western Washington data.

3.3 Recurrence Interval Rainfall Values Versus Probable Maximum Precipitation Relations

3.3.1 Data and Unadjusted Relations

In this method of estimating PMP, we developed a relation of 100-yr rainfall to MAP using data from southeast Alaska. For 15 stations well distributed geographically throughout southeast Alaska, 100-yr, 24-hr rainfall values were determined. Although it would have been desirable to use additional stations, the daily data for other stations had too many periods of missing or accumulated data to permit reliable frequency determinations for the rarer recurrence intervals. The plot of the 100-yr, 24-hr rainfall values vs. MAP with a computed linear regression line is shown in figure 17 (identification numbers on station data points on the figure refer to table 12). The correlation coefficient is 0.72, and the standard error of estimate 1.9 in. (48 mm). A plot of maximum observed 24-hr precipitation amounts for 49 stations in southeast Alaska vs. MAP reinforced the relation shown in figure 17. These data are discussed in section 3.5.2.1.

3.3.2 Adjustment of Relation for Estimating Probable Maximum Precipitation

The linear relation from figure 17 "predicts" 100-yr, 24-hr rains from MAP. In order to predict PMP from MAP, the basic relation (fig. 17) needs to be transformed. This comes from application of a general relation between PMP to 100-yr ratios and MAP. Plots of PMP/100-yr ratios vs. MAP characteristically show considerable scatter. However, a definite characteristic trend prevails in that PMP/100-yr ratio increases with smaller values of MAP. This has been noticed in numerous PMP studies that embrace regions with a large range in MAP. The most recent of these studies covers the southwest United States (Hansen, et al. 1977).

Figure 8.10 in Hydrometeorological Report No. 36 (U.S. Weather Bureau, 1961) indicates that the lowest PMP/100-yr ratios (inverse of numbers shown on figure 8.10 in that report) in California may be below 2.0. A characteristic value for both coastal mountainous areas and the Sierra Nevada in California where MAP is large is about 2. For the areas on figure 8.10 of Hydrometeorological Report No. 36 encompassed by PMP/100-yr ratios of less than 2, an overall average MAP of about 45 in. (1143 mm) prevails. According to our frequency-adjusted curve of figure 16, this 45 in. (1143 mm) would be adjusted to a comparable southeast Alaska MAP of about 220 in. (5588 mm). In the more protected portions of the Sacramento and the San Joaquin Valleys, a PMP/100-yr ratio of around 2.5 is characteristic. Where the San Francisco Bay "opening" to moisture influx influences Sacramento Valley precipitation (more characteristic of the "broken-up" character of the Southeast Alaska terrain), a PMP/100-yr ratio of 2.2 is characteristic. The MAP of approximately 20 in. (508 mm) characteristic of this California 10 in. (254 mm) MAP characteristic of this California region adjusts for southeast Alaska by (fig. 16) to a comparable southeast Alaska value of about 50 in. (1270 mm).

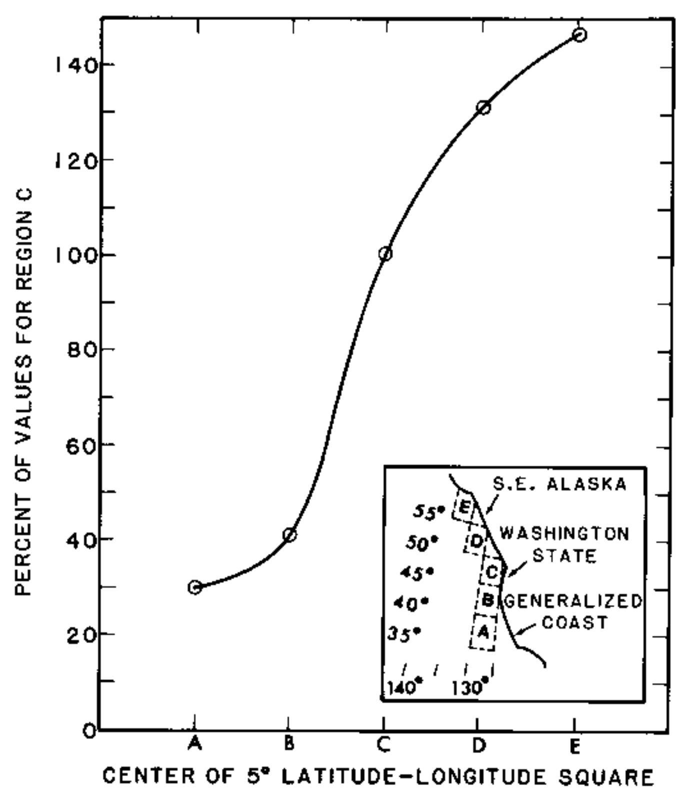


Figure 16.—Variation of frequency of lows with latitude offshore of west coast of North America.

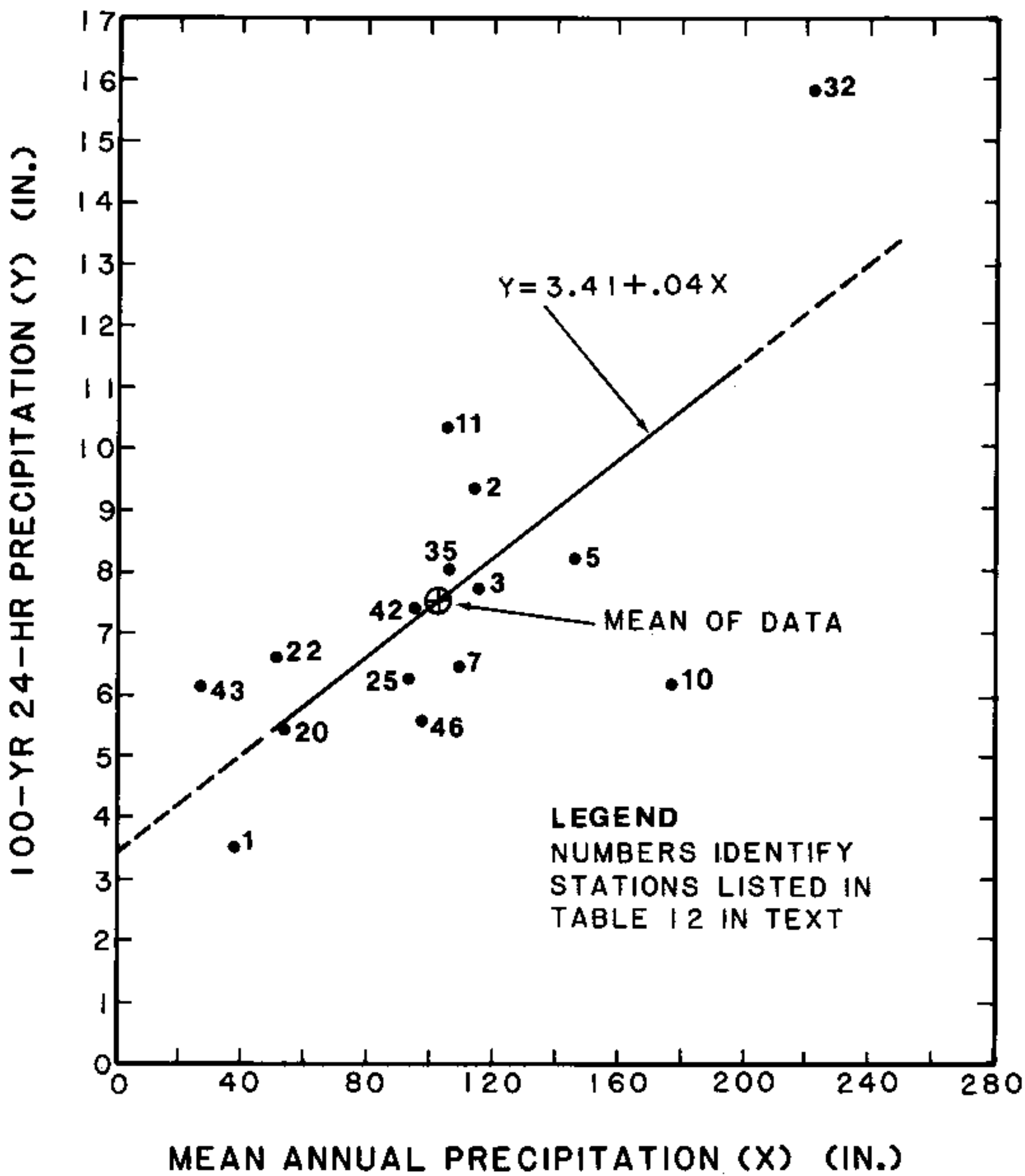


Figure 17.—100-yr, 24-hr precipitation vs. mean annual precipitation for southeast Alaska data.

We chose the low-lying area around but mostly west of Portland, Oregon to investigate the variation of PMP to 100-yr ratios for another area where the MAP ranges from 40 to 60 in. (1016 to 1524 mm). This low-lying area between the coast range and the Cascades most closely mimics upwind barrier effects for those areas of southeast Alaska where the MAP drops well below the coastal values. Based upon 14 grid points (with 1/4 degree spacing) within about 40 mi (64 km) of Portland, the mean PMP/100-yr ratio is 2.3 and the MAP is 50 in. (1270 mm). By use of the relation in figure 16, a MAP of 50 in. (1270 mm) at the latitude of Portland, Oregon, adjusts to about 90 in. (2286 mm) for southeast Alaska.

Table 12.—Stations used to develop recurrence interval versus probable maximum precipitation relations

Station Index No.	Station	Lat. (°)	Lat. (')	Long. (°)	Long. (')	Elev. ft.	Elev. m	Length of record yrs.	100-yr 24-hr precip. in.	100-yr 24-hr precip. mm	Mean annual precip. in.	Mean annual precip. mm
1	Angoon	57	30	134	35	35	11	29	3.53	90	38	965
2	Annette (R)	55	02	131	34	110	34	29	9.33	237	114	2896
3	Annex Creek	58	19	134	06	24	7	53	7.74	197	114	2896
5	Baranof	57	05	134	50	20	6	24	8.22	209	147	3734
7	Bell Island	55	55	131	35	10	3	21	6.47	164	109	2769
10	Cape Decision	56	00	134	08	39	12	27	6.15	156	77	1956
11	Cape Spencer	58	12	136	38	81	25	34	10.36	263	105	2667
20	Gustavus FAA	58	25	135	42	22	7	31	5.44	138	54	1372
22	Haines Terminal	59	16	135	27	175	53	13	6.64	169	52	1321
25	Juneau City	58	18	134	24	25	8	54	6.29	160	93	2362
32	Little Port Walter	56	23	134	39	14	4	34	15.83	402	222	5639
42	Sitka Magnetic	57	03	135	20	67	20	35	7.48	190	96	2438
43	Skagway	59	27	135	19	18	5	29	6.17	157	27	686
46	Treepoint Light Station	54	48	130	56	36	11	37	4.93	125	98	2489
48	Wrangell	56	28	132	23	37	11	50	5.59	142	80	2032

The PMP/100-yr ratio adopted for adjusting the basic figure 17 relation ranged from near 2.4 at a MAP of 50 in. (1270 mm), near 2.2 at a MAP of 100 in. (2540 mm), and near 1.8 at a MAP of 220 in. (5588 mm). The resulting transformed curve relating MAP to PMP (rather than 100-yr rain to PMP) is shown in figure 18. This transformed linear regression is the second method for making a first approximation to point PMP estimates.

3.4 Combination of the Methods for First Approximation Probable Maximum Precipitation

The (ratio-adjusted and frequency-adjusted) linear relations from the two methods of relating PMP to MAP are shown on figure 18. The adopted relation is also shown on this figure. Neither of the separate relations provides, by itself, acceptable results. A better solution is believed to be obtained by a combination of the two methods. We adopted the mean of the two linear relations for MAP values above 100 in. (2540 mm) but a nonlinear modified relation for

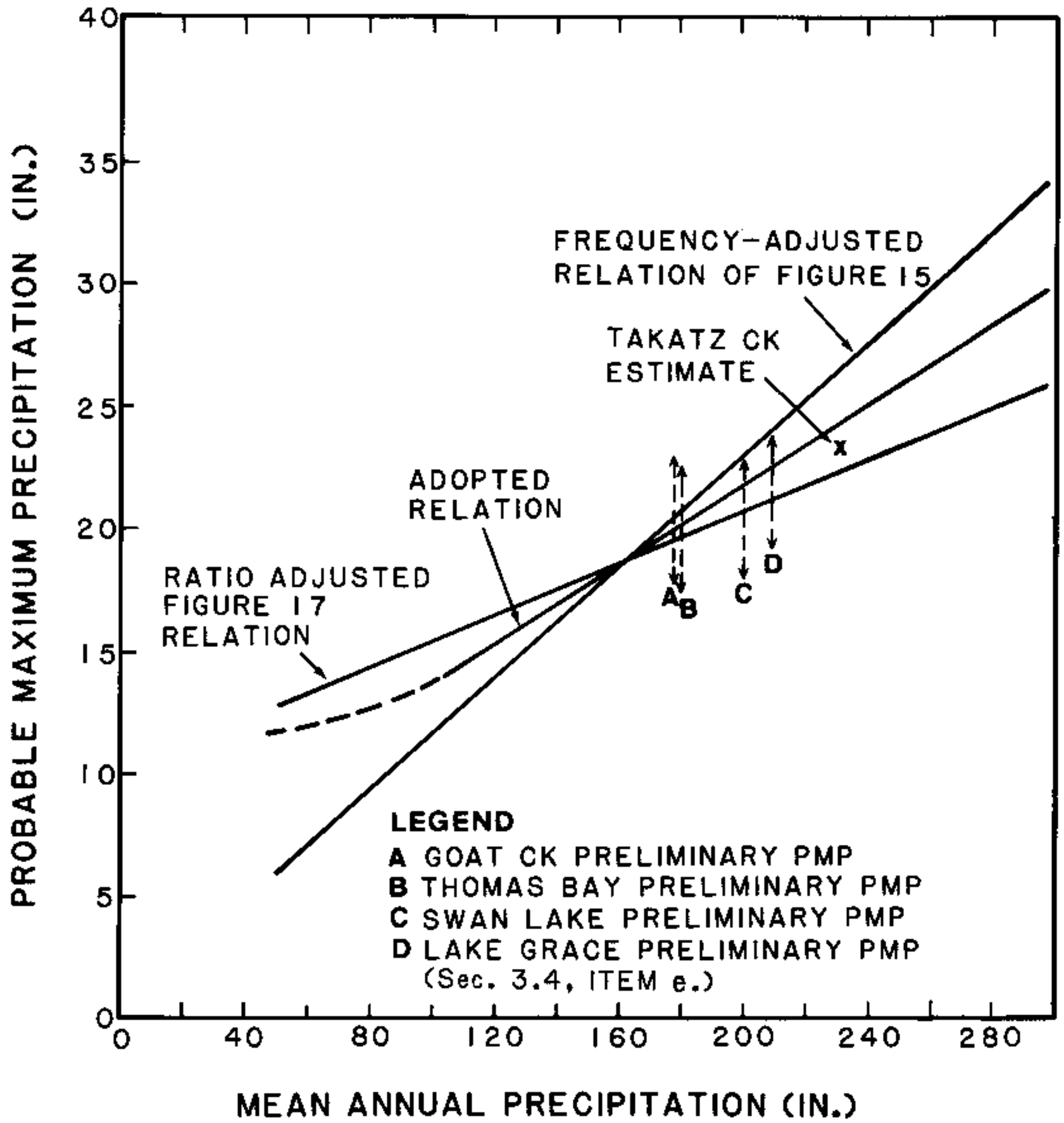


Figure 18.—Adjusted linear relations from figures 15 and 17, adopted linear relations and comparisons.

lesser MAP values. The dashed portion of the curve on figure 18 shows a variation in this adopted modification from linearity. The reasons for preferring a combination rather than the individual relations are:

a. Extension of the Washington frequency-adjusted linear relation of figure 18 PMP to MAP (fig. 15) to low values of MAP suggests practically no PMP as MAP approaches zero. Extension of the same relation to a MAP of 300 in. (7620 mm) in southeast Alaska gives a 24-hr, 10-mi^2 (26-km^2) PMP of well over 30 in. (762 mm) (see point c.)

b. We considered a study of PMP in 1967 for the Takatz Creek drainage on Baranof Island as providing a valid general level of 24-hr 10-mi^2 (26-km^2) PMP for the type of orography existing in that basin. This estimate involved orographic computations for the upslopes on Baranof Island. In addition, confirmation of the general level of total 24-hr PMP was provided by tie-ins with western United States estimates (U.S. Weather Bureau, 1961) by means of an earlier (1961) estimate for Bradley Lake, near the south coast of Alaska.

c. We suggest that for the study area (except possibly the steep upslopes in the extreme northwest portion) just slightly over 30 in. (762 mm) in 24 hours should be the upper limit to PMP for the regions of the most extreme orographic effects. Parts of Baranof Island are somewhat more orographically affected than the Takatz Creek basin and should have larger PMP values than for the Takatz Creek drainage.

In the extreme northwest portion of the study area, there are areas near the coast where significant ground slopes extend up to 6,000 to 7,000 ft (1,800 to 2,100 m) or higher. Such conditions exist in the Olympic Mountains of Washington and for some areas in southern California where the 24-hr PMP exceeds 30 in. (762 mm). Since the extreme upslope conditions of the Olympic Mountains are duplicated only in the extreme northwest part of our Alaskan study area, we judge only in this limited region of our study area should we exceed the 30 in. (762 mm) value.

d. Adoption of the Washington curve results in too drastic a departure from the adopted smooth trend in PMP/100-yr ratios as the MAP approaches 50 in. (1270 mm). For example, for a MAP of 50 in. (1270 mm), the 100-yr, 24-hr value from figure 17 is 5.21 in. (133 mm). The frequency-adjusted Washington relation (fig. 15) gives only slightly more than this resulting in a PMP/100-yr ratio only slightly over unity. At a MAP of 200 in. (5080 mm), the 100-yr 24-hr value from figure 17 is 11.21 in. (285 mm) while the frequency-adjusted Washington relation (fig. 15) gives about 23 in. (584 mm) for a ratio near 2. Thus, the departure from the suggested trend (using the frequency-adjusted Washington relation) is so great that the desired trend (higher PMP/100-yr ratios for smaller MAP) is actually reversed. Contrasted to this reversal, the adopted relation (see fig. 18) results in a PMP/100-yr ratio of 2.2 based on an 11.91-in. (302-mm) PMP for a MAP of 50 in. (1270 mm) and a ratio of 1.9 based upon a

21.8-in. (554-mm) PMP for a MAP of 200 inches (5080 mm). Thus, the adopted relation preserves an appropriate trend in PMP/100-yr ratios that allows for increases in the ratio as MAP lowers below 50 in. (1270 mm).

e. Four recent Hydrometeorological Branch studies (A, B, C, and D on figure 18) giving ranges* in PMP values took into account differences in orographic features between each of these basins, respectively, with orography in and surrounding the Takatz Creek drainage. In addition to this relating the orography to that in and near Takatz Creek, several other techniques were used for estimating a range of PMP values for these basins. These techniques (used for obtaining a range in PMP values) involved:

1. Use of a tentative generalized rainfall-elevation relation.

2. Adjustment of a record September 1918, 3-day rainfall at Ketchikan.

3. Comparison with Technical Paper No. 47 values.

4. Use of a 24-hr, 10-mi^2 (26-km^2) PMP to 100-yr, 24-hr point precipitation.

Not all of these techniques are completely independent of procedures developed for this generalized approach. However, there is sufficient independence in these estimates, to use the range in PMP values for judgment in reference to the general level resulting from the adopted generalized relation.

3.4.1 Additional Support for Combined Relation

The discussions in sections 3.4.1.1 and following provide additional support for the adopted nonlinear relation for MAP values less than 100 in. (2540 mm).

3.4.1.1 Use of Largest Probable Maximum Precipitation Amounts From the Contiguous United States. Using the contiguous United States as a much larger sampling region, we can consider the 24-hr PMP for such a region as a rough approximation to estimating nonorographic PMP for southeast Alaska. Use of the maximum Gulf of Mexico coast nonorographic PMP as a guide for southeast Alaska nonorographic PMP suggests that a linear extension of the adopted

* A range in PMP values was given in each of those estimates pending completion of this generalized study.

relation below a MAP of 100 in. (2540 mm) produces a PMP that is too low. This use of the coastal Gulf of Mexico value involved an adjustment for moisture and a storm mechanism adjustment. A dual adjustment is realistic as both relative moisture charge and relative differences in storm types and, thus, possibly storm efficiencies are important.

The basic contiguous U.S. PMP value used in this technique derives from a recent report of PMP for the Eastern United States (Schreiner and Riedel, 1978). Along the Gulf coast, the adopted 24-hr, 10-mi^2 (26-km^2) amount is 47.1 in. (1196 mm). The primary storm support for this PMP value came from the slowly moving or slowly looping Hurricane Easy in September 1950 whose track was in the eastern Gulf of Mexico off the west coast of Florida. The storm produced an observed 24-hr, 10-mi^2 (26-km^2) amount of 38.7 in. (983 mm) centered at Yankeetown, FL. In southeast Alaska, the midlatitude disturbance in the fall is the efficient precipitation producer. It is difficult to conceive of such a mid-latitude storm mechanism being as efficient in <u>concentrating rainfall</u> as the slowly moving or looping Hurricane Easy. However, experience indicates that it is difficult to quantify such differences in efficiency. Thus, just a "token" efficiency adjustment of -10 percent is added to the primary adjustment for moisture availability in the new location.

We have assumed a "token" efficiency adjustment of -10 percent, realizing insufficient knowledge exists to really quantify such a factor. However, we do believe the 10-percent figure may be conservatively low on the basis that no known occurrence of repeating "efficient" thunderstorms or stationary Low's has produced a 24-hr rainfall equal to that measured in the looping Yankeetown hurricane. It is important to remember that, in this comparison of storm efficiencies, we are concerned with the rainfall potential for a 24-hr duration. Other factors become important when dealing with significantly shorter or longer durations and different adjustments in efficiencies may be appropriate.

The moisture adjustment of the Gulf coast 47.1-in. (1196-mm) PMP value for use in southeast Alaska gives a range in values from 15.1 in. (384 mm) in the north to 16.3 in. (414 mm) in the south based upon the range of 12-hr persisting 1,000-mb (100-kPa) dew points in southeast Alaska for October of 53.5°F (11.9°C) to 55°F (12.8°C) compared to the maximum Gulf of Mexico coast dew point of 78°F (25.6°C) associated with the summer or early fall storm of tropical origin. The additional -10 percent efficiency adjustment reduces the adjusted values to a range of 13.6 to 14.7 in. (345 to 373 mm). A -20 percent efficiency adjustment would result in a range of values from 12.2 to 13.2 in. (310 to 335 mm).

3.4.1.2 Nonorographic Probable Maximum Precipitation Based on Northwest United States Mean Annual Precipitation. An independent method that led to another estimate of nonorographic PMP for southeast Alaska suggested a 24-hr nonorographic PMP of 12 to 14 in. (305 to 356 mm).

Briefly summarized, this method involved:

1. Estimating nonorographic coastal MAP from the latitude of Washington to southeast Alaska.

2. Using nonorographic MAP estimates to determine <u>average</u> orographic effects for extensive inland areas for Washington, British Columbia, and southeast Alaska for MAP.

3. Determining average orographic effects similar to (2) for Washington for 24-hr PMP.

4. Estimating nonorographic PMP off southeast Alaska from values determined in (1), (2), and (3).

Detailed MAP analysis (fig. 19) show coastal Washington State MAP values about 70 in. (1778 mm) ranging from about 65 in. (1651 mm) in the south to about 75 in. (1905 mm) in the north (U.S. Weather Bureau, 1965). In order to estimate roughly how much orography contributes to an average 70-in. (1778-mm) MAP value, we turned to the generalized PMP study for the Northwest States (U.S. Weather Bureau, 1966). Orographic factors near the coast in this study were, first, a 20-percent "stimulation" that was placed in the convergence component of the PMP and, second, an orographic PMP index 6-hr value of 0.5 in. (12.7 mm). Considered together in relation to total PMP, the total orographic effect for coastal PMP amounts to about 30 percent (from "weighting" of total coastal PMP by convergence and orographic components). Thus, if we assume that the stimulation and upwind effects in the MAP (percentagewise) are similar to that for the PMP, then 50 in. (1270 mm) is a reasonable estimate of non-orographic offshore MAP for the coast of Washington State.*

The analyzed MAP chart for our study area (fig. 4) suggests an average coastal MAP of 100 in. (2540 mm) or a little more. A tabulation of MAP was made for southeast Alaska coastal and/or near coastal stations (table 13).

The 165 in. (4191 mm) at View Cove exceeds all others (table 13) by a considerable margin. This suggests the MAP for this station may have been additionally augmented by local terrain conditions and may not be representative of general coastal MAP values. A mean computed by elimination of the value at View Cove is 101 in. (2565 mm). Using the 30 percent orographic adjustment determined for coastal Washington and considering both means suggests an offshore MAP (rounded as with the Washington coast estimate) of about 75 in. (1905 mm).

Using the estimated MAP for offshore Washington State of 50 in. (1270 mm) and for offshore southeast Alaska of 75 in. (1905 mm), we now estimate a value for the British Columbia Pacific Coast by interpolating from figure 16. By this technique we came up with 65 in. (1651 mm) for coastal British Columbia.

These adopted nonorographic MAP values for offshore Washington, British Columbia, and southeast Alaska were used to estimate average orographic effects on MAP. For these estimates, rather large inland areas were chosen opposite each of the designated offshore areas. In outlining the areas for which such

*A reasonable assumption when we consider a large portion of the MAP in this region is made up from general storm events that are smaller events, nevertheless some meteorological causes similar to those that would cause the PMP-event.

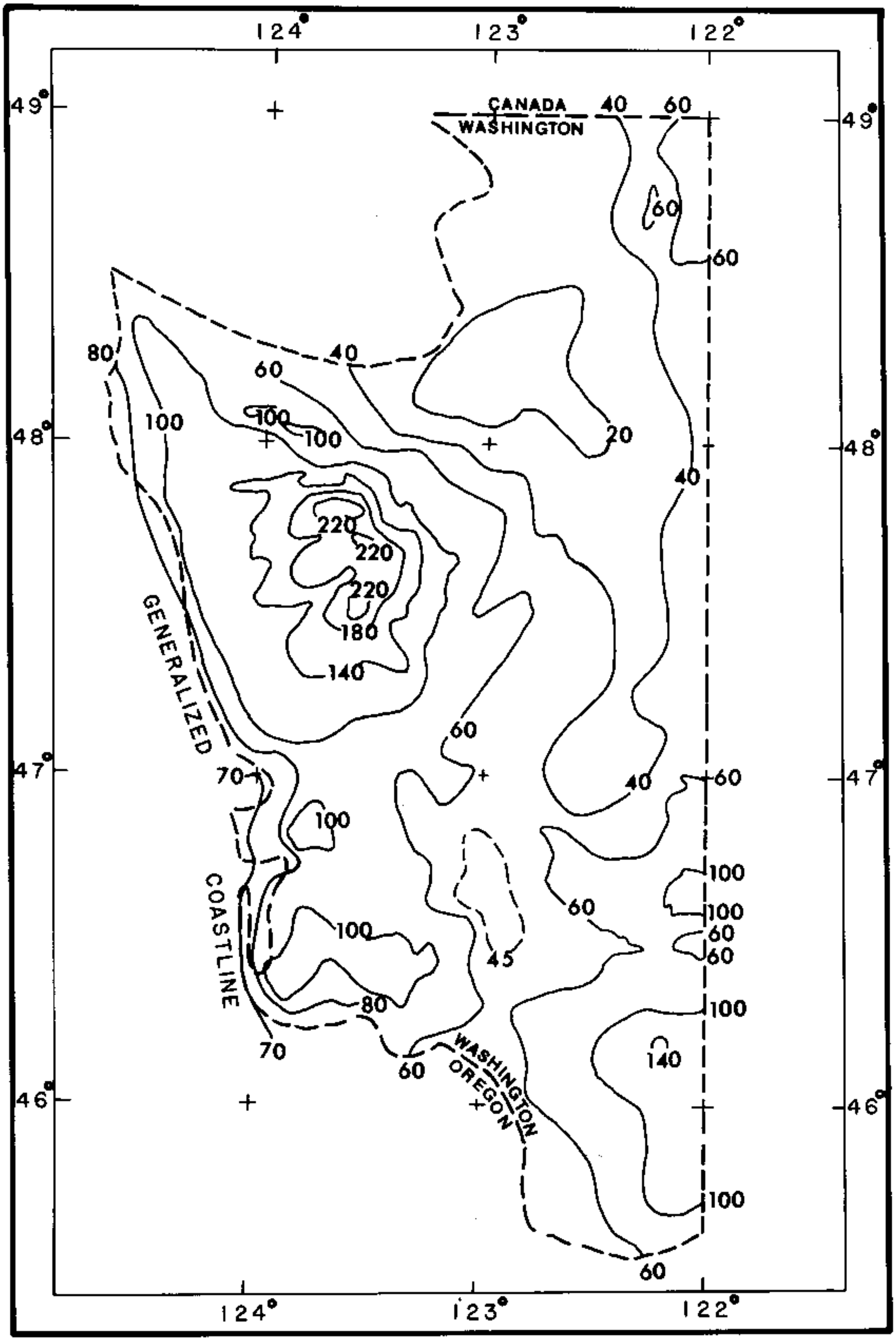


Figure 19.—Area in Washington used for determining average orographic effects. Isolines are mean annual precipitation in inches.

orographic effects were determined, we need to keep in mind the primary purpose to be served by these estimated orographic effects. This purpose was to form judgments on the relation of PMP to MAP, and the general level of PMP.

Table 13.—Mean annual precipitation for coastal and near coastal stations in southeast Alaska

Station Index No.	Station	Mean annual precipitation in.	mm
2	Annette	114	2896
10	Cape Decision	77	1956
11	Cape Spencer	105	2667
12	Chicagof	130	3302
38	Radioville	100	2540
41	Sitka FAA	89	2261
42	Sitka Magnetic	96	2438
46	Treepoint Light Station	98	2489
47	View Cove	165	4191
	Mean	108	2743

The complicated and "broken-up" characteristic of topography in our study area favors much variation in orographic effects. However, except for the extreme northwest portion of the study area, there are no especially high and extensive barriers. By contrast, both the British Columbia and western Washington State test areas have some extensive upslopes rising to 6,000 ft (1,829 m) or higher. Such extensive slopes produce both unusual increases (upslope) and decreases (downslope) in precipitation, and thus in MAP. Such extensive barriers also mean, on the average, greater inland sheltering downwind of the most prominent barriers. The use of rather large areas, so as to incorporate a reasonably substantial amount of topography similar to southeast Alaska, helps to make the resulting ratios more meaningful than if small areas with associated greater uncertainty were used. The areas chosen for British Columbia and for western Washington are shown in figures 19 and 20, respectively. For our study area and the other two areas, MAP values at grid points (with 1/4° spacing) were averaged and from this gridding mean orographic increases were determined for each inland area on the basis of a comparison with the adopted offshore non-orographic MAP value for each of the three areas: 50, 65, and 75 in. (1270, 1651, and 1905 mm), respectively. These increases are shown in table 14.

Table 14.—Mean orographic increases

Area	Category	Net orographic percent
Washington	MAP	33
British Columbia	MAP	40
Southeast Alaska	MAP	68
Washington	PMP	38
Oregon	PMP	31

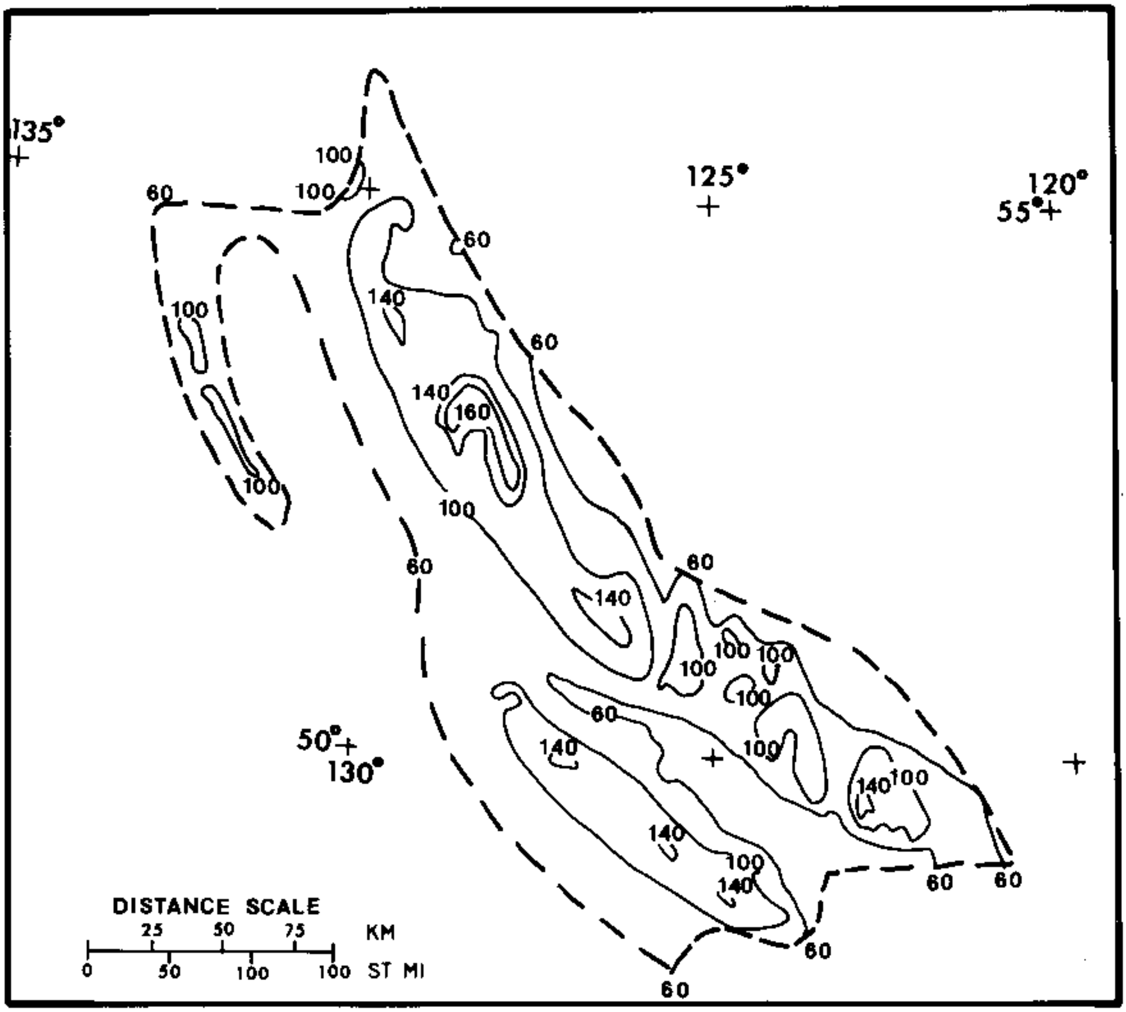


Figure 20.--Area in British Columbia used for determining average orographic effects (after Walker, 1961). Isolines are mean annual precipitation in inches.

A comparison of net orographic effects using generalized PMP values for the Northwest States, (U.S. Weather Bureau, 1966) for the area west of 122°W. in Washington resulted in an average inland orographic effect of +38 percent. The basis for this was the use of an offshore 12-in. (305-mm) nonorographic 24-hr, 10-mi^2 (26-km^2) PMP. Similarly, for the portion of Oregon west of 122° W., the average orographic effect was computed to be +31 percent. These values are also shown in table 14.

The trend in overall net orographic effects for the MAP category compared to the Washington area showed an increase from Washington to British Columbia with an additional and more pronounced increase for southeast Alaska. We suggest this increasing trend northward is largely due to the increasing net orographic exposure (directionwise) that exists northward along the coast. This greater exposure directionwise allows MAP to build up more to the north as more variation in wind direction can be utilized efficiently both during a particular storm and among different storms. In addition, for the western Washington and Oregon areas, inland of the coastal mountains, there is more substantial sheltering than in British Columbia and especially more so than in southeastern Alaska. Using rather large areas integrated these various factors.

3.5 First Approximation of Probable Maximum Precipitation and Modification

3.5.1 First Approximation of Probable Maximum Precipitation

We used the MAP chart (fig. 6) and the adopted relation of figure 18 to give a first approximation to 24-hr, 10-mi^2 (26-km^2) PMP. This resulted in a range of PMP values from a minimum of 12 in. (305 mm) to a maximum of 28 in. (711 mm). This range in PMP values is for a range of MAP values of from 50 to 300 in. (1270 to 7620 mm).

We now make use of the data of table 14 for an evaluation of reasonable assumptions of various magnitudes of nonorographic offshore PMP. In connection with such an evaluation, we also should be aware that prior PMP estimates for the Pacific coastal region of the United States indicated only small variations in the nonorographic 24-hr 10-mi^2 (26-km^2) PMP with latitude. Apparently, the lowering moisture values with increasing latitude are counter-acted by stronger winds. Thus, as these two factors combine, there is a limitation of the latitudinal variation of moisture convergence that takes part in the production of maximum nonorographic rainfall.

Using the mean first approximation 24-hr 10-mi^2 (26 km^2) PMP for the study area (fig. 1), which was estimated to be 18.3 in. (465 mm) with an assumed 12 in. (305 mm) nonorographic 24-hr, 10-mi^2 (26-km^2) PMP, gives a mean indicated orographic increase of 52 percent. Assuming a 14-in. (356-mm) non-orographic value makes the orographic increase 32 percent. This range of 32 to 52 percent brackets the mean of 42 percent from the five individual percentages of table 14. Percentages go well outside this range of 32 to 52 percent when we assume either a 10-in. (254-mm) (83 percent) or a 16-in. (406-mm) nonorographic PMP (16 percent). From these comparisons we conclude, therefore, that the best estimate of nonorographic component lies between 12 and 14 in. (305 and 356 mm). This range in 24-hr 10-mi^2 (26-km^2), PMP is close to the range one obtains utilizing the U.S. maximum PMP with an efficiency adjustment (to supplement the moisture adjustment) of -10 to -20 percent (sec. 3.4.1.1).

3.5.2 Modification of First Approximation Probable Maximum Precipitation

The first approximation PMP (not shown) was derived from a straightforward objective application of the adopted relation of MAP to PMP from figure 18 to the MAP chart (fig. 6). Modification to this first approximation came from the following sources:

a. Relation of station maximum 24-hr precipitation values to MAP and resulting anomaly analysis.

b. Conclusions of significant features of heavy precipitation-producing weather situations in southeast Alaska with particular attention to orographic effects.

c. Trying various techniques for estimating the general level of PMP for the most protected regions between the coast and the interior continental upslopes.

3.5.2.1 Relation Between Maximum Observed 24-hr Precipitation and Mean Annual Precipitation. There were 49 stations in southeast Alaska where daily or hourly data were available to determine maximum 24-hr precipitation amounts. For these stations (table 15), a relation was developed between the maximum observed values and MAP. For those stations listed in table 15 where only maximum observation-day rains of record were available, 24-hr maxima were estimated by increasing the daily observation-day maximum by 13 percent (U.S. Weather Bureau, 1960).

The plot of 49 station maximum 24-hr amounts versus MAP and the fitted linear regression are shown in figure 21. The correlation coefficient is 0.68 and the standard error of estimate 1.5 in. (38 mm). The departure of the individual values of figure 21 from the regression line were used in an anomaly analysis as an aid to adjusting PMP values from the first approximation PMP map derived using the MAP as an index.

3.5.2.1.1 Anomaly analysis. For the study area, a large number of the stations whose maximum daily rains exceeded the values indicated by the mean relation of figure 21 were found to be located in protected areas. This indicated that 24-hr rainfall potential for such sheltered or protected areas was greater than that estimated from a long-duration index such as the MAP. The analysis of the anomalies (not shown) also indicated that, in general, greater PMP potential than that tied to the MAP was indicated from about 56°N northward.

3.5.2.2 Clues from Storm Situations. Weather maps for a selection of heavy rain cases were investigated with the objective of finding clues for the logical adjustment of the PMP. Many different weather systems were investigated. Four cases were especially helpful in providing insight into the adjustment of the PMP maps.

3.5.2.2.1 August 3-7, 1920. This was an outstanding storm producing a 1-day rain of 8.20 in. (208 mm) at Ketchikan on August 5. The 3-day rain (19.54 in., 496 mm) for this storm was used with adjustments as one technique for estimating a range in PMP for specific basins (sec. 3.4). Assuming the isobar orientation (fig. 22) is indicative of the flow at about 2,000 ft (610 m) or so above sea level, we suggest that rather strong orographic effects around Ketchikan, for example, were part of the causes of the rainfall in this storm. Winds at very low levels would avoid barriers, while at around 2,000 ft (610 m) the winds could overtop upwind barriers and thereby utilize the southwest-facing upslopes of this area for adding an orographic component to the rain.

3.5.2.2.2 September 25-28, 1918. Record 1-day rains occurred in this storm at Juneau City, Perserverance Camp, and Speel River (table 15). Although the strong on-shore gradient and rapidly moving systems are features common to many storms that affect our study area, the pronounced backing of the low-level winds (indicated by the orientation of the isobars on the surface chart for the 26th compared to the isobar orientation the following morning) suggested a departure of flow that permitted a more effective avoidance of barriers than is ordinarily the case in intense low-pressure systems. Surface weather maps for this storm are shown in figure 23.

Table 15.--Station precipitation data for southeast Alaska

Index no.	Station	Lat. (°)	Lat. (')	Long. (°)	Long. (')	Elevation (ft.)	Elevation (m)	Daily maximum (in.)	Daily maximum (mm)	1.13 X daily maximum (in.)	1.13 X daily maximum (mm)	Date	Length of record (yrs)*	Mean annual precipitation (in.)	Mean annual precipitation (mm)
1	Angoon	57	30	134	35	35	11	2.40	61	2.71	69	9/19/42	29	38	965
2	Annette (R)	55	02	131	34	110	34	7.59	193	-	-	10/20-21/58	29	114	2896
3	Annex Creek	58	19	134	06	24	7	6.05	154	6.84	174	10/13/45	53	114	2896
4	Auke Bay	58	23	134	38	42	13	2.87	73	3.24	82	9/29/70	8	62	1575
5	Baranof	57	05	134	50	20	6	5.98	152	6.76	172	10/14/42	24	147	3734
6	Beaver Falls	55	23	131	28	35	11	6.70	170	7.57	192	9/23/67	24	151	3835
7	Bell Island	55	55	131	35	10	3	4.60	117	5.20	132	10/2/30	21	109	2769
8	Calder	56	10	132	27	20	6	4.54	115	5.13	130	1/13/22	13	112	2845
9	Canyon Island	58	33	133	41	85	26	3.98	101	4.50	114	2/24/38	9	61	1549
10	Cape Decision	56	00	134	08	39	12	4.66	118	-	-	10/25-26/44	27	77	1956
11	Cape Spencer	58	12	136	38	81	25	8.60	218	-	-	10/21-22/48	34	105	2667
12	Chicagof	57	40	136	05	10	3	4.78	121	5.40	137	9/13/52	6	130	3302
13	Craig	55	29	133	09	15	5	5.15	131	5.82	148	10/5-6/46	17	111	2819
14	Eldred Rock	58	58	135	13	55	17	7.03	179	7.94	202	10/24/47	26	46	1168
15	Five Finger Light Sta.	57	16	133	37	70	21	3.55	90	4.01	102	8/10/69	28	56	1422
16	Fortmann Hatchery	55	36	131	25	132	40	5.10	130	5.76	146	8/10/15	13	150	3810
17	Glacier Bay	58	27	135	53	50	15	3.63	92	4.10	104	8/23/66	5	81	2057
18	Guard Island	55	27	131	53	20	6	4.47	114	5.05	128	11/16/43	22	66	1676
19	Gull Cove	58	12	136	09	18	5	6.50	165	-	-	10/9-10/46	12	99	2515
20	Gustavus FAA	58	25	135	42	22	7	3.69	94	4.17	106	10/6/43	31	54	1372
21	Haines 1 S	59	14	135	26	100	30	5.64	143	-	-	10/9-10/44	32	61	1549
22	Haines Terminal	59	16	135	27	175	53	3.76	96	4.25	108	12/5/64	17	50	1270
23	Hollis	55	28	132	40	15	5	5.06	129	5.72	145	10/14/61	10	103	2616
24	Hydaburg (Sulzer)	55	12	132	49	25	8	6.07	154	6.86	174	11/14/17	5	142	3607
25	Juneau City #2	58	18	134	24	25	8	5.64	143	-	-	9/25-26/18	54	93	2362
26	Juneau WBAP (R)	58	22	134	35	12	4	4.66	118	-	-	10/9-10/46	28	54	1372
27	Kake	56	59	133	57	8	2	3.84	98	4.34	110	10/29/30	11	56	1422
28	Kasaan	55	38	132	34	28	9	3.53	90	3.99	101	12/17/19	15	86	2184
29	Ketchikan	55	21	131	39	15	5	8.07	205	9.12	232	8/5/20	54	162	4115
30	Lincoln Rock L.S.	56	03	132	46	25	8	4.30	109	-	-	2/20-21/47	22	64	1626

Table 15.—Station precipitation data for southeast Alaska (continued)

Index no.	Station	Lat. (°)	Lat. (')	Long. (°)	Long. (')	Elevation (ft.)	Elevation (m)	Daily maximum (in.)	Daily maximum (mm)	1.13 X daily maximum (in.)	1.13 X daily maximum (mm)	Date	Length of record (yrs)*	Mean annual precipitation (in.)	Mean annual precipitation (mm)
31	Linger Longer	59	26	136	17	700	213	2.80	71	3.16	80	11/25/63	7	34	864
32	Little Port Walter	56	23	134	39	14	4	14.84	377	16.77	426	12/6/64	34	222	5639
33	Moose Valley	59	25	136	03	400	122	4.75	121	5.37	136	10/29/49	12	31	787
34	Perserverance Camp	58	18	134	20	1400	427	7.40	188	8.36	212	9/26/18	4	155	3937
35	Petersburg	56	49	132	57	50	15	5.70	145	6.44	164	10/21/37	40	106	2692
36	Point Retreat Light	58	25	134	57	20	6	5.65	144	6.38	162	12/28/56	23	71	1803
37	Port Alexander	56	15	134	39	18	5	7.62	194	8.61	219	7/7/52	14	176	4470
38	Radioville	57	36	136	09	15	5	6.81	173	7.70	196	10/13/39	15	100	2540
39	Seclusion Harbor	56	33	134	03	20	6	5.24	133	5.92	150	11/30/36	9	115	2921
40	Shelter Island	58	23	134	52	10	3	2.88	73	3.25	82	2/9/30	15	55	1397
41	Sitka FAA	57	04	135	21	15	5	5.37	136	6.07	154	9/20/54	23	89	2261
42	Sitka Magnetic	57	03	135	20	67	20	6.42	163	7.25	184	9/9/48	73	96	2438
43	Skagway	59	27	135	19	18	5	5.25	133	-	-	10/9-10/44	29	27	686
44	Speel River	58	08	134	44	15	5	8.86	225	10.01	254	9/26/18	9	139	3531
45	Tenakee	57	47	135	12	19	6	4.17	106	4.71	120	10/30/49	8	64	1626
46	Treepoint Light Sta.	54	48	130	56	36	11	4.50	114	5.09	129	9/23/67	37	98	2489
47	View Cove	55	04	133	04	13	4	5.51	140	6.23	158	12/15/36	15	165	4191
48	Wrangell	56	28	132	23	37	11	4.51	115	5.10	130	1/30/62	50	80	2032
49	Yakutat WBAP (R)	59	31	139	40	28	9	7.13	181	-	-	11/27-28/56	49	132	3353

- Recorder (not adjusted by 1.13)
* Data through 1972

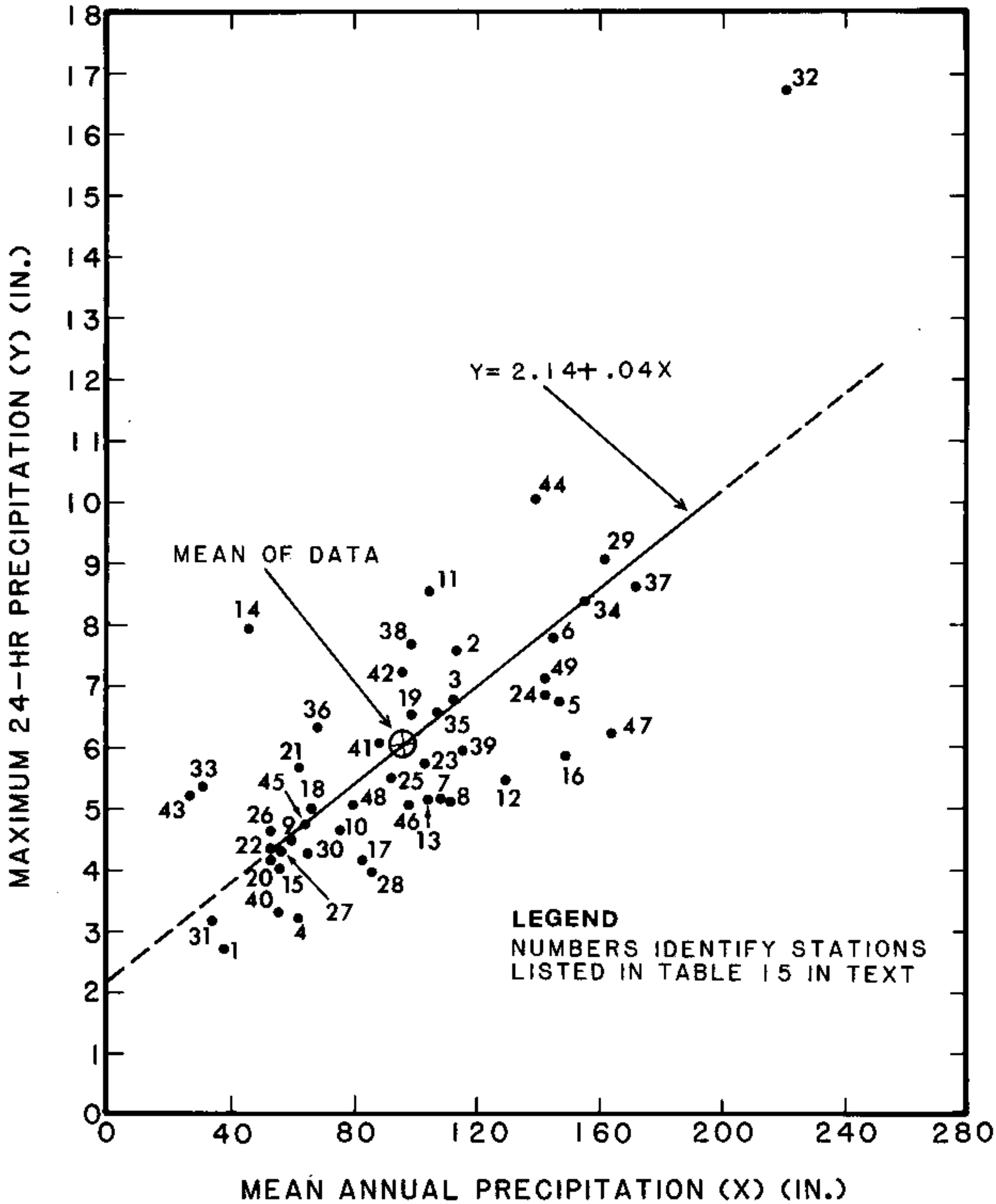
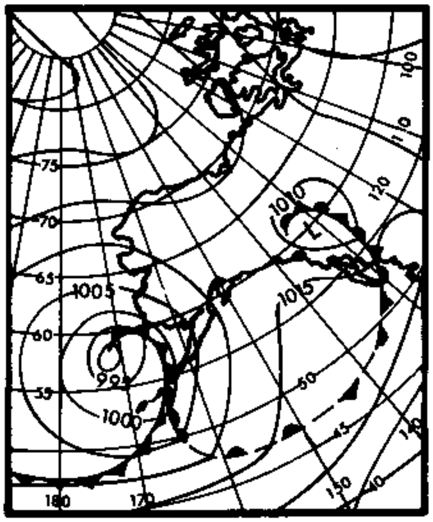


Figure 21.—Maximum observed 24-hr precipitation vs. mean annual precipitation for southeast Alaska.



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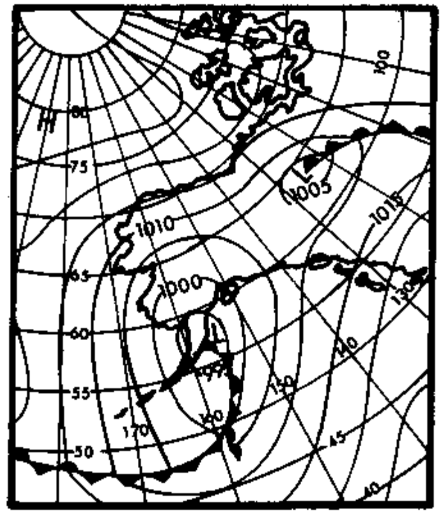

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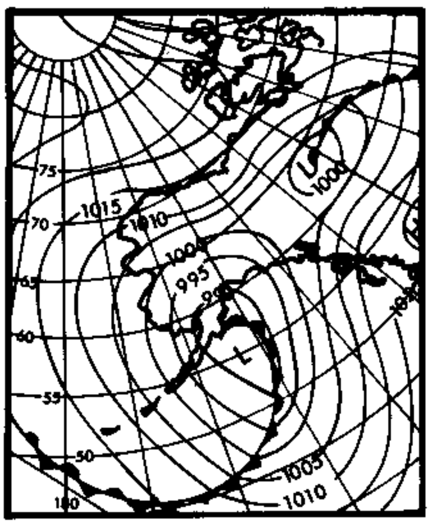

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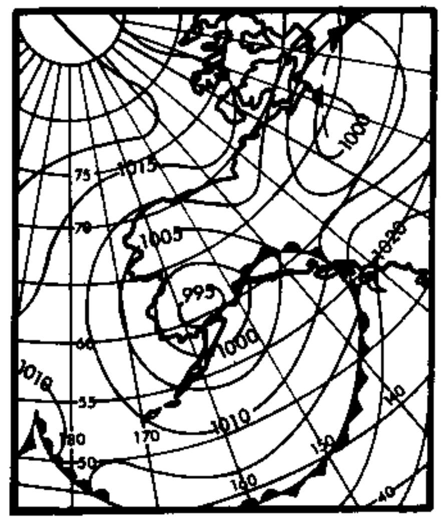

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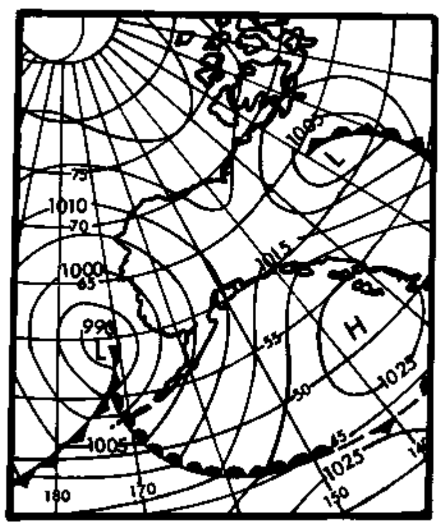
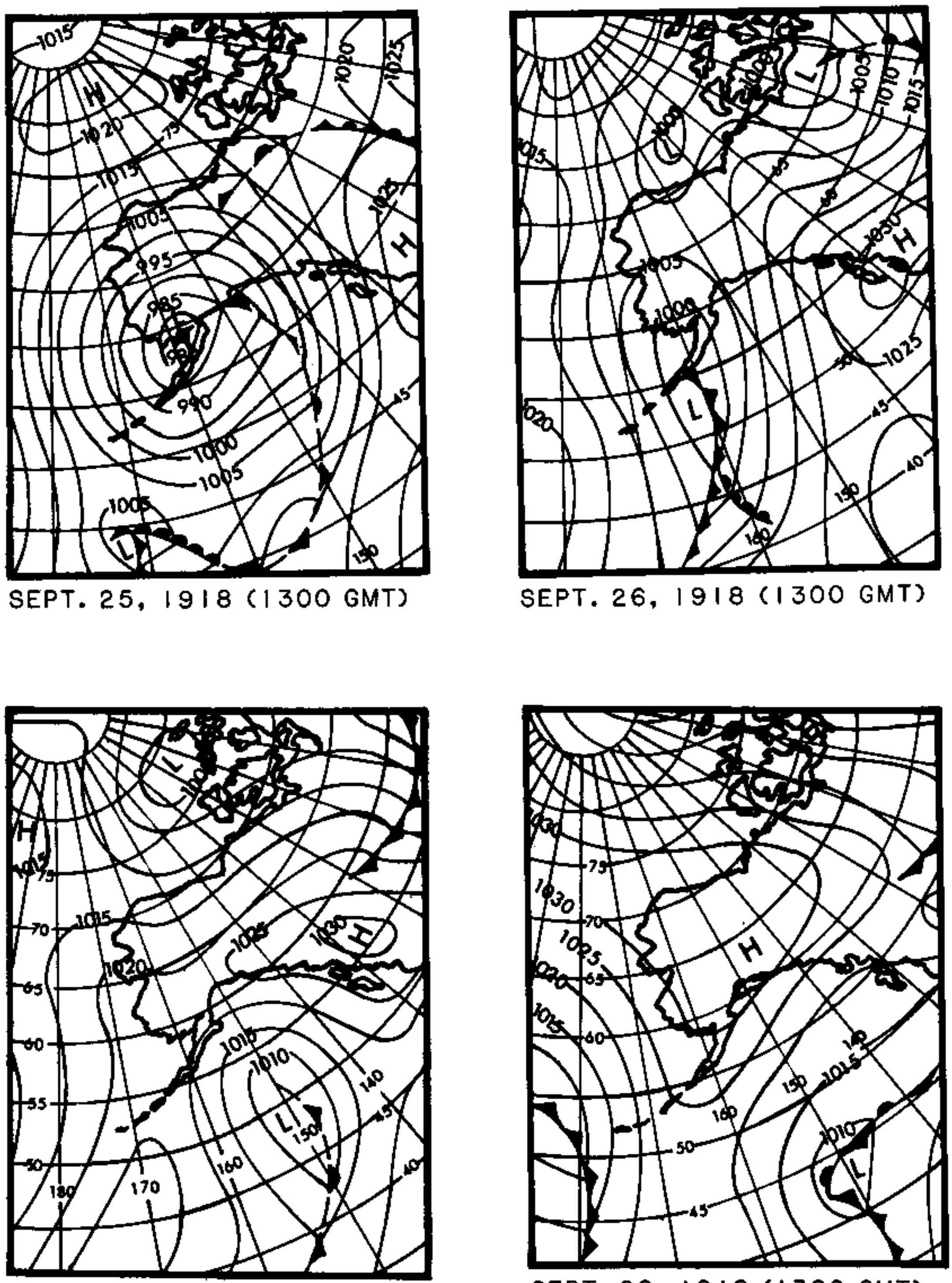


AUG. 7, 1920 (1300 GMT)

Figure 22.--Surface weather maps for August 3-7, 1920.



SEPT. 25, 1918 (1300 GMT)

SEPT. 26, 1918 (1300 GMT)

SEPT. 27, 1918 (1300 GMT)

SEPT. 28, 1918 (1300 GMT)

Figure 23.--Surface weather maps for September 25-28, 1918.

3.5.2.2.3 **December 4-7, 1964.** Surface maps for this storm are shown in figure 24 and upper-air (500-mb) charts in figure 25. Except that the maps indicate an intense system with strong flow from a low latitude, definitive features of why unusual rains resulted are not evident. The surface and 500-mb charts for this storm show that our study area in general is in about the center of the strongest on-shore flow through the lower levels of the atmosphere.This particular storm produced record rains at both a very rainy location, Little Port Walter where the MAP is 222 in. (5639 mm), and at a very sheltered or dry location, Haines Terminal, where the MAP is only 50 in. (1270 mm). The amount at Haines Terminal is a higher percentage of it's MAP than the value at Little Port Walter.

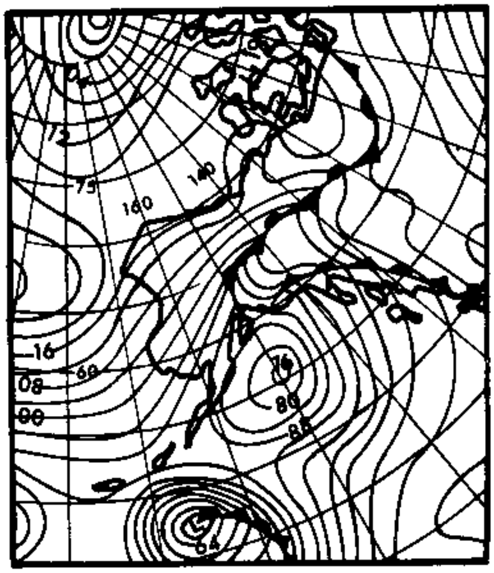
3.5.2.2.4 **July 6-11, 1969.** This heavy rain producing midsummer storm which gave Little Port Walter 9.55 in. (243 mm) on July 9 is illustrative of the fact that basically the same type of broadscale weather situation is responsible for summer rains as well as cool-season rains. Figure 26 shows the surface maps for this storm beginning with the map for July 8.

3.5.2.2.5 **Summary.** Based partly upon the clues from the four specific storm cases but also on others for which maps are not shown, one should be quite liberal in permitting variation in the PMP gradients, etc., that are not adequately defined by a relation of PMP to MAP. Topographic features, for example, as indicated on a topographic map (or a generalized version of such a map) should be given careful consideration in making adjustments to a first approximation of a PMP map that is influenced strongly by the MAP distribution. In other words, we know from what is possible in wind variations, etc., in rain-producing systems that slopes facing varying directions may be utilized more efficiently in particular situations than one would judge from MAP variations only. Thus, knowing the weather variations possible, one needs to give keen attention to the topography in making adjustments to the first-approximation chart.

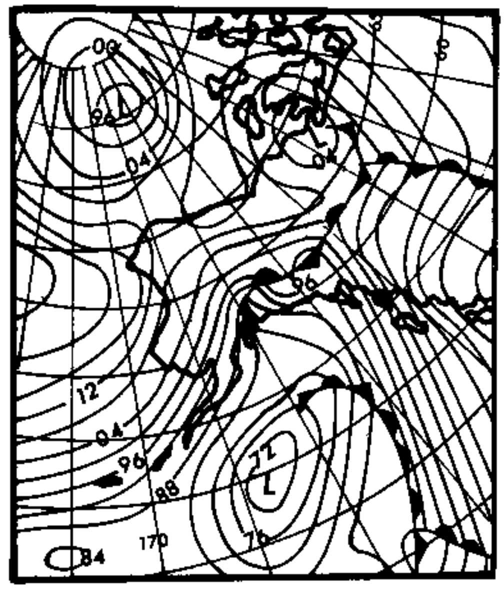
The survey of weather features in large precipitation-producing storms in southeast Alaska showed that one can only guess how the interplay of winds with the complicated topography results in a significant rain at a particular place, e.g., storm of December 4-7, 1964 (sec. 3.5.2.2.3). We know from experience that for other areas of complicated orography somewhat altered weather conditions may increase the rainfall potential, especially in ordinarily "sheltered" regions where MAP and other such indices do not give sufficient clues to the full potential. Toward this end an evaluation of the orography in relation to the rare event is essential in the modification of the first-approximation PMP chart.

The following are suggested as clues to modifying the MAP features for greater consistency in PMP conditions from our study of heavy general rain cases in this orographic region:

a. Situations that involve rapidly changing winds or situations with a distinct (and somewhat out-of-the-ordinary) variation of wind with height may promote more efficient rain production in a particular area. Judgment on the tie-in with the particular orographic configurations of an area must be made.



DEC. 4, 1964 (1200 (GMT)



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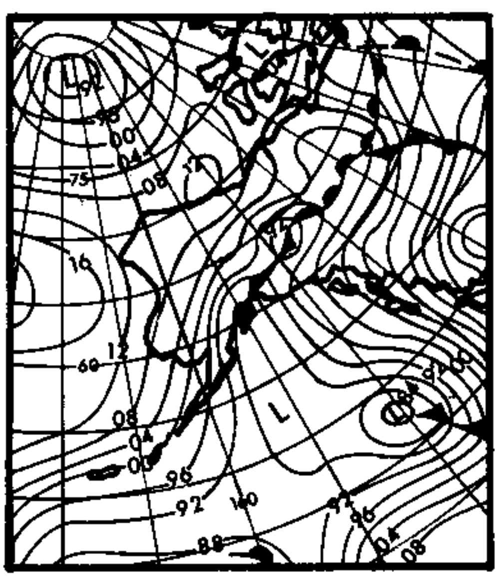

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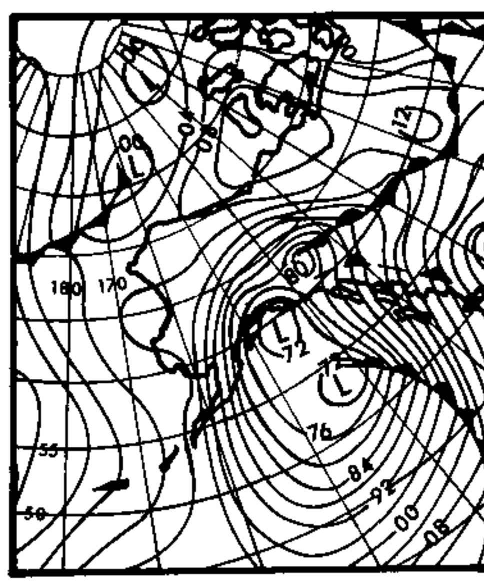
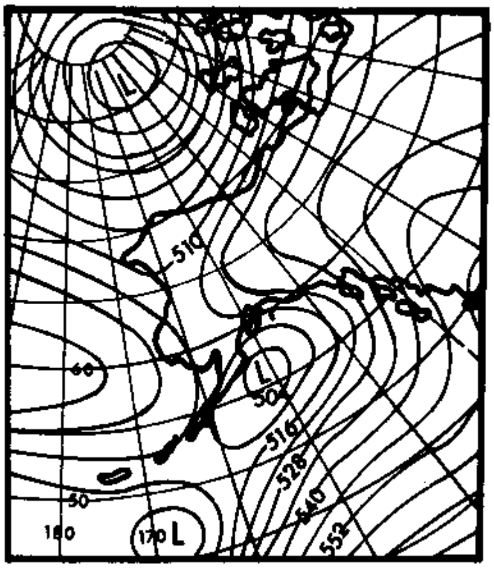


DEC. 7, 1964 (1200 GMT)

Figure 24.—Surface weather maps for December 4-7, 1964.



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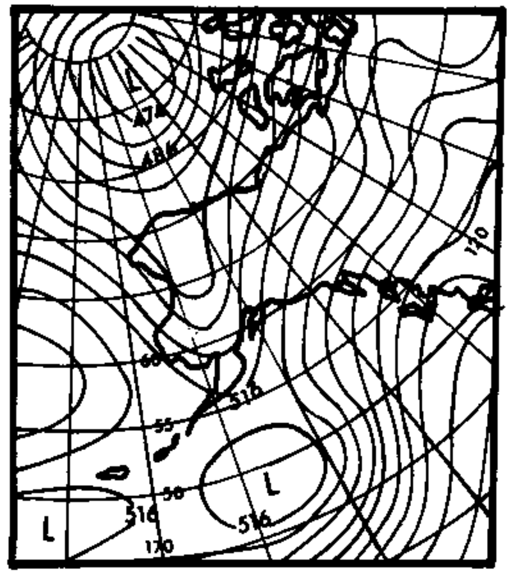

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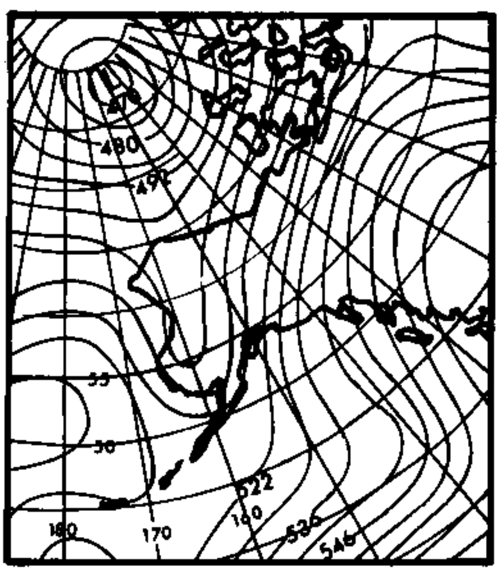

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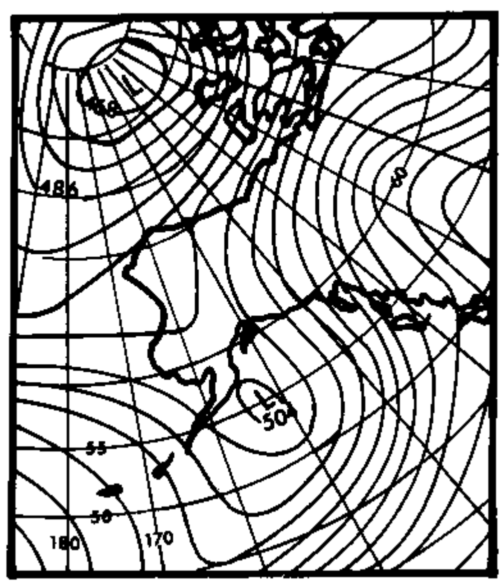

DEC. 7, 1964 (1200 GMT)

Figure 25.—Upper-air (500-mb) weather maps for December 4-7, 1964.

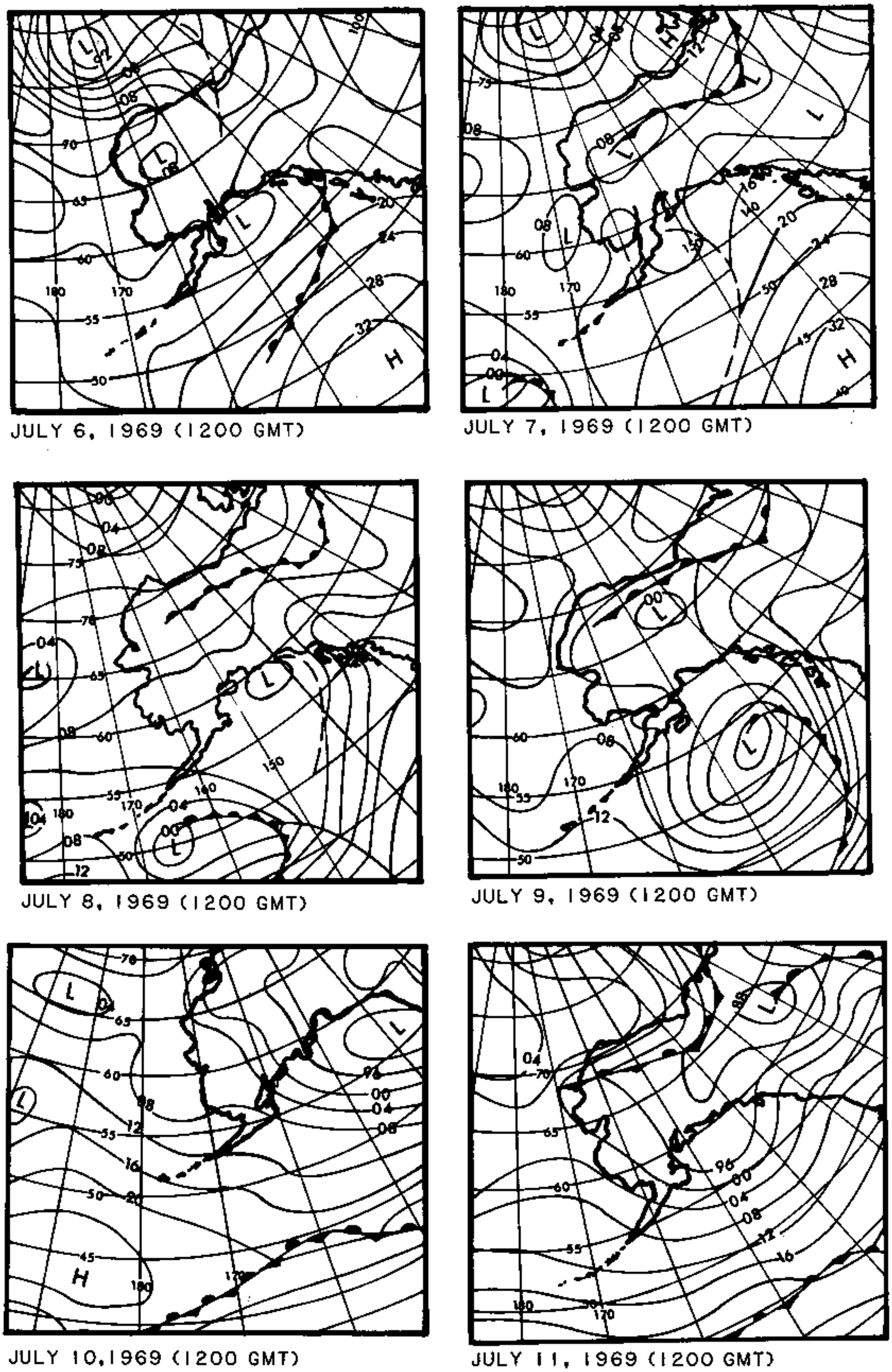

Figure 26.—Surface weather maps for July 6-11, 1969.

b. Situations involving rapid motion and/or strong fronts may produce large convergence components of precipitation allowing relatively "protected areas" to receive more precipitation than one might other-wise assign to such areas.

c. We know that many slight variations in prevailing synoptic weather patterns are possible. These variations during a storm may promote the efficient integrated use of prevailing topography in particular regions. Persistence magnifies such effects with time. For example, around Ketchikan, low level winds from the south could be channeled by the terrain. Contrasting to the low-level wind effects in this area, winds a few thousand feet higher need to vary in direction in order to utilize particular orographic upslopes. A particular slope may have its effect on rainfall accentuated more during a single storm event than in the MAP.

3.5.2.3 Establishment of the Probable Maximum Precipitation General Level for Sheltered Region. In a recent generalized PMP estimate for the Southwest States (Hansen et al., 1977), nearly all areas were considered susceptible to at least some orographic rainfall in the PMP storm. Following this principle which (for ordinarily sheltered areas) is based mainly upon "carry-along" of precipitation particles, we should expect some net positive orographic effect in the PMP in all places in southeast Alaska. Since the overall orographic sheltering in southeast Alaska is generally less than in the Southwest States, the orographic effects in southeast Alaskan sheltered areas should be more than minimal.

To evaluate the first-approximation PMP in sheltered areas, we start with the range of nonorographic PMP estimates from the offshore MAP approach (sec. 3.4.1.2) of 12 to 14 in. (305 to 356 mm) and the values based on United States nonorographic values (sec. 3.4.1.1) of 13.7 to 14.7 in. (348 to 373 mm). Combining these, we will use a rounded range of about 12 to 15 in. (305 to 381 mm). What we wish to determine is what the magnitude of the PMP ought to be in the portions of the interior of southeast Alaska where the PMP is believed to be the lowest (i.e., the most sheltered regions where we postulate some positive orographic effect is still realistic).

Using a PMP 12-hr persisting dew point of 55°F (12.8°C) with a 2,000-ft (610-m) barrier gives an adjustment of -22 percent. This is based upon a moist adiabatic vertical distribution of moisture associated with the 1,000-mb, 12-hr persisting dew point of 55°F (12.8°C). The 12- to 15-in. (305- to 381-mm) range of non-orographic values, by applying the -22 percent, becomes 9.4 to 11.7 in. (239 to 297 mm). Computations are also made using a 1,000-ft (305-m) barrier. The resulting reduction is -12 percent. Thus, the adjusted PMP estimates for the 1,000-ft (305-m) barrier are 10.6 to 13.2 in. (269 to 335 mm).

To sum up the above results:

a. Unsheltered non-orographic PMP - 12 to 15 in. (305 to 381 mm).

b. 1,000-ft (305 m) barrier PMP - 10.6 to 13.2 in. (269 to 335 mm).

c. 2,000-ft (610-m) barrier PMP - 9.4 to 11.7 in. (239 to 297 mm).

These values (depending upon barrier assumptions) represent minimum PMP values when we assume zero net orographic effects. A modest net orographic component assumption for all areas as in the recent report on PMP for the southwest states (Hansen et al., 1977) requires increasing these values.

3.5.2.4 Examples of Modifications to First-Approximation Probable Maximum Precipitation. In the vicinity of the main coastline or segments of coastlines facing the ocean, first-approximation PMP values are increased approximately 20 percent for stimulation and upwind upslope effects (sec. 3.4.1.2). Such effects on rainfall are not adequately portrayed in terms of the tie-in of PMP with a generalized MAP chart.

Conforming to the overall indications of the anomaly analysis (sec. 3.5.2.1.1), changes to the first approximation PMP south of about 56°N. were kept quite small. However, just north of 56°N is a region (between 132°W and 134°W. and up to 57°N.) comprised of numerous islands. On the whole, this is an area that may be classified as being sheltered. Hence, in line with previous points, an overall increase of PMP is suggested for this area (sec. 3.5.2.1.1 and 3.5.2.2.5). However, 5 or 6 sub-areas (within this rather large area) with the most favorable upslopes were singled out for somewhat higher increases than the overall general average for the area. In addition, our aim was to make these adjustments so that consistency in overall detail would result for the whole study area.

Bordering the main interior upslopes in the west (north of 57°N.) is an extensive long body of water called Stephens Passage. To the west of Juneau, the water extends to the northwest where it joins the Lynn Canal. We increased the PMP about 4 inches over most of these protected water areas and over the adjoining areas of upslope. We judge in such protected or sheltered areas that specific wind conditions (so as to utilize particular upslopes, etc.) can produce PMP values reasonably above those derived from a straight-forward objective tie-in with MAP that gives the first-approximation values. In the extreme northern part of the Lynn Canal, and nearby surroundings, we do not significantly increase the PMP for two reasons:

a. This area is so extremely well sheltered we did not consider it realistic to depart significantly from the first-approximation value.

b. To give a minimum PMP higher than 13 in. (330 mm) in this area would make this extremely sheltered region's PMP too high in relation to less well-sheltered areas. In other words, for consistency the general level of all sheltered areas would need to be raised (sec. 3.5.2.3).

Another modification to the first-approximation chart involved an increase in the areal coverage of the maximum PMP on the interior upslopes. This procedure resulted in increases in PMP due to the stimulation effects at the lower elevations and due to upslope effects at the higher elevations.

In the extreme northwest portion of our study area, some extreme and extensive upslopes exist (associated with the Fairweather mountain range). In this area, we have placed a small 10-mi^2 (26-km^2) PMP of 32 in. (813 mm). This is in agreement with the general level of PMP discussed earlier (sec. 3.4) in connection with similar extreme and extensive upslope conditions along the west coast region of the United States.

3.5.3 Adjusted 24-hr, 10-mi^2 Probable Maximum Precipitation Chart

Using such guidance as discussed under 3.5.2, the first-approximation PMP chart was adjusted. The final PMP is shown in figure 27. The absolute range in PMP values is from a low of 13 in. (330 mm) to a high of 32 in. (813 mm). When compared to the first-approximation values, adjusted PMP values in many sheltered regions were raised 2 to 3 in. (51 to 76 mm) with some increases of around 4 in. (102 mm).

3.6 Summary Remarks

Maximum use was made of southeast Alaskan data for developing a PMP chart with a realistic degree of orographic detail. A primary aim was to provide realistic consistency, particularly with regard to orography, in basin PMP estimates. The degree of detail is greater than the earlier generalized study (Miller, 1963). We believe the detail is consistent with that of other recent studies in regions of complicated topography (e.g., Hansen et al., 1977).

3.7 Seasonal Variation of Probable Maximum Precipitation for Basins in Southeast Alaska

Due to the possibility that snowmelt, combined with less than the all-season PMP, might produce a more critical flood, an estimate of PMP for use in the snowmelt season is necessary. The adopted seasonal variation of PMP is based upon a synthesis of previous seasonal variation work for Alaska with some additional data analysis and regional smoothing of adopted relations.

3.7.1 Data and Analysis

A summary of the maximum daily rains of record for the 49 stations listed in table 15 substantiates the conclusions regarding season of extreme rains from prior individual basin estimates and from Technical Paper No. 47 (Miller, 1963). The most obvious conclusion from the summary of maximum rains in table 15 is that October is the month most likely to experience maximum daily rains in southeast Alaska. The table 15 summary put in the form of a histogram of months of maximum daily rains is shown in figure 28.

For the purpose of defining a PMP during the snowmelt season for southeast Alaska, we need to consider variation in winds, storm efficiency, moisture, etc. Other studies north and south of our region have previously investigated these material variations. In Washington, the all season PMP can occur in October and early winter (U.S. Weather Bureau 1966). To the north of our study area along the south coast of Alaska, several estimates of PMP by the Hydrometeorological Branch (U.S. Weather Bureau 1961, 1969, National Weather Service 1975) have shown the all-season PMP occurring in August and September. We consider this a realistic latitudinal trend.

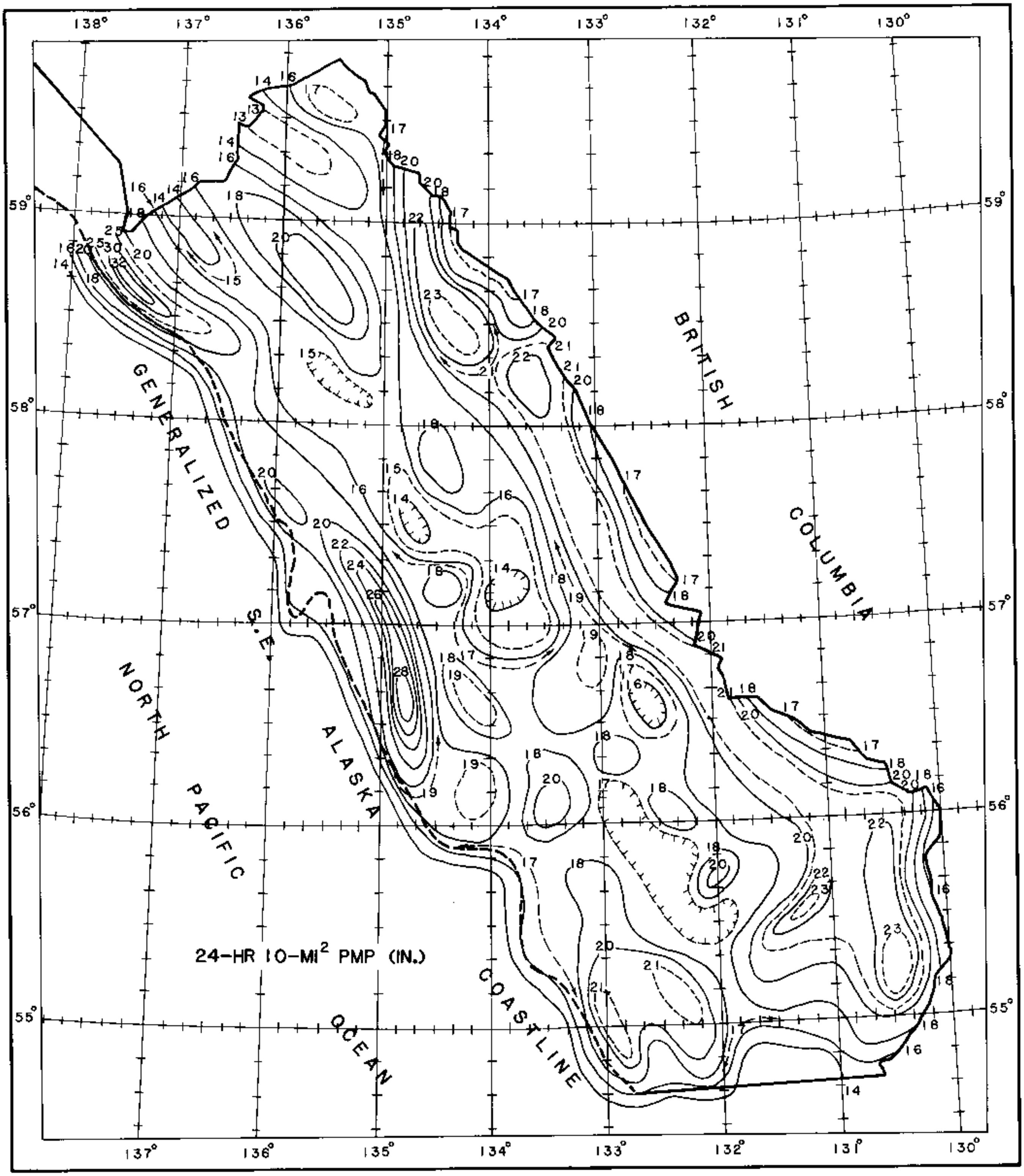

Figure 27.—24-hr 10-mi^2 (26-km^2) PMP (in.) for Southeast Alaska.

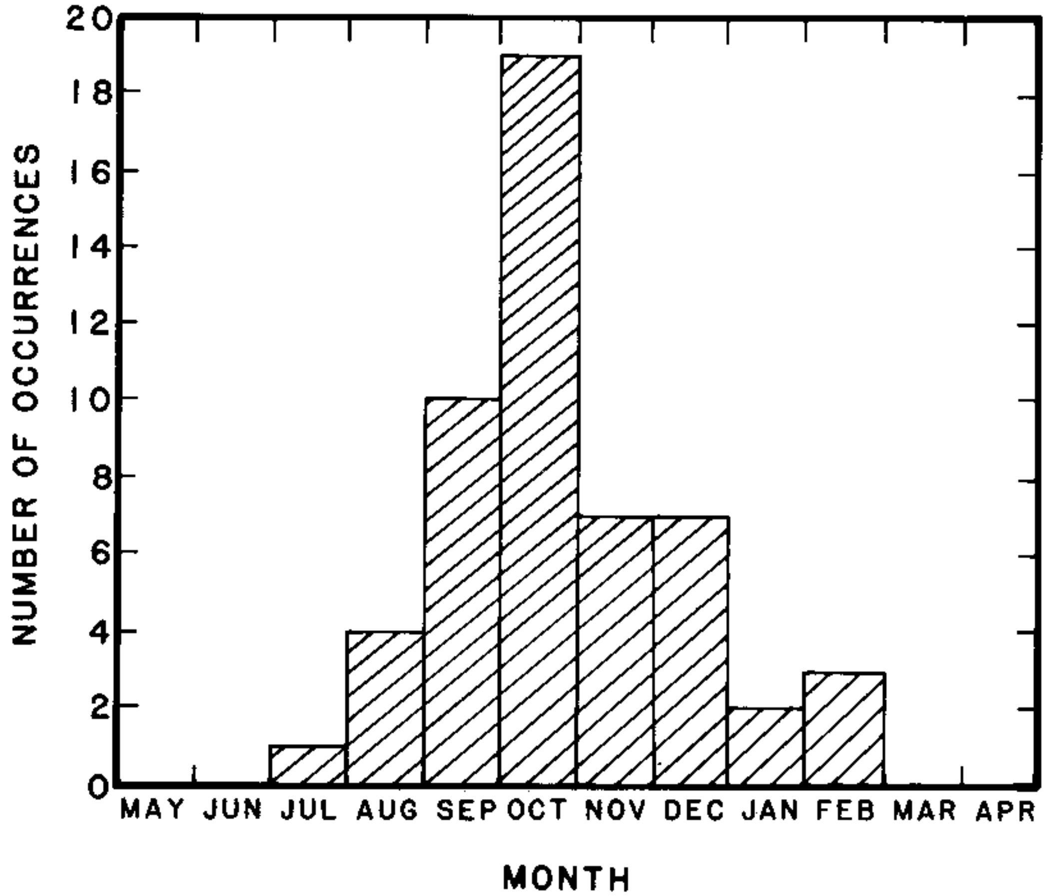

Figure 28.—Histogram of month of occurrence of maximum daily precipitation.

3.7.2 Conclusion

The adopted seasonal variation relation for southeast Alaska of figure 29 results in the seasonal variation percentages shown in table 16. We recommend interpolating appropriate percentages from table 16 to apply to the all-season PMP to obtain PMP for combination with snowmelt.

Table 16.—Seasonal variation in percent of October 1 probable maximum precipitation

Date	PMP (percent of October 1)	Date	PMP (percent of October 1)
October 1	100	September 15	99
September 1	98	August 15	96
August 1	92	July 15	87
July 1	80	June 15	72
June 1	70	May 15	70
May 1	73	April 15	79

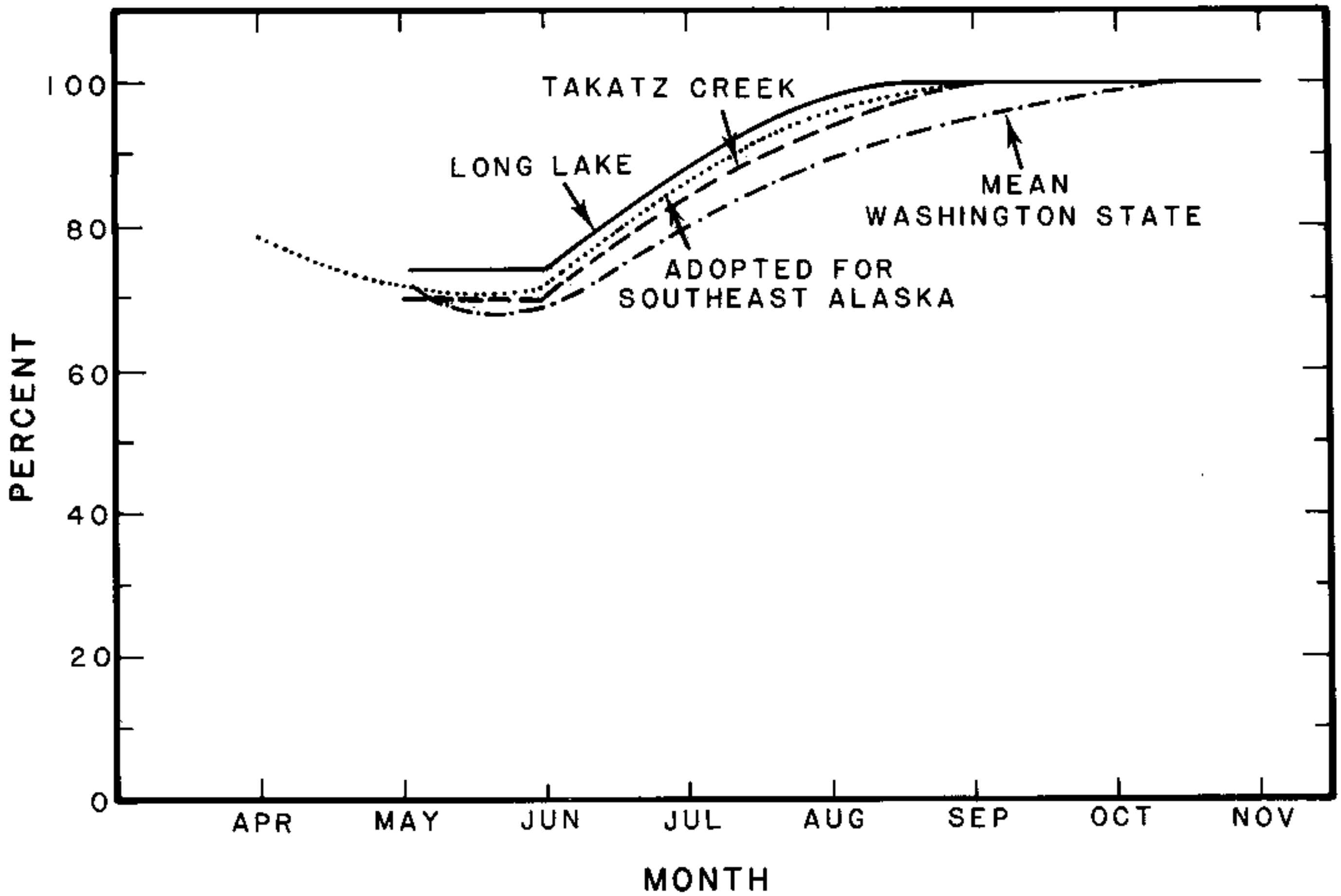

Figure 29.—Seasonal variation of probable maximum precipitation for southeast Alaska. (See fig. 5 for location of Long Lake and Takatz Creek.)

3.8—Depth-Area-Duration Relations for Southeast Alaska Probable Maximum Precipitation

The basic PMP chart (fig. 27) for southeast Alaska is for 24 hr 10 mi^2 (26 km^2). Depth-area-duration (DAD) relations are presented for areas to 400 mi^2 (1,036 km^2) and durations to 72 hr. Since the 24-hr, 10-mi^2 (26-km^2) value is the basic value, all DAD values are given in percent of the 24-hr, 10-mi^2 (26-km^2) values.

3.8.1 Depth-Area-Duration Relations to 24 hours

Figure 2.16 of <u>Technical Paper No. 47</u> (Miller, 1963) gives depth-area percentages for PMP to 400 mi^2 (1,036 km^2) for durations of 6, 9, 12, 18 and 24 hours. This provides the basis for developing depth-area relations for durations to 24 hours for southeast Alaska PMP. In order to move from the depth-area relations (Miller 1963) to a set of DAD relations to 24 hours for the southeast portion of Alaska, the following are considered.

A 6- to 24-hr ratio of about 0.50 is characteristic for total PMP along the west coast of the contiguous United States. The similarity of the PMP storm type across latitude supports such similarity of ratios from the states of California to Washington. A comparable maritime climatic regime for storm situations prevails in southeast Alaska and along the south coast of Alaska. The adopted 6- to 24-hr ratio for the Bradley Lake PMP estimate (U.S. Weather Bureau 1961) was just under 0.50 while most previously made individual estimates for southeast Alaska basins have had adopted 6- to 24-hr ratios near or slightly over 0.50. Since the orographic component of the total PMP has ratios well below 0.50, one should expect the total PMP 6- to 24-hr ratio to drop a little below 0.50 for those basins where the orographic component makes up a large portion of the total PMP. A summary of maximum 24-hr rains at Annette and Juneau led to an overall average 6- to 24-hr ratio of about 0.40. Our depth-area and depth-duration ratios apply to an index of total PMP in southeast Alaska. Thus, we have adopted a 6- to 24-hr ratio of 0.50 as a good overall value for this area.

A smooth depth-duration relation making use of the adopted 6- to 24-hr ratio of 0.50 is provided by figure 2.14 in Technical Paper No. 47. The information in this figure is used to obtain ratios appropriate for 10 mi^2 (26 km^2) for discrete durations to 24 hours.

Combining the above depth-area and depth-duration ratios gives us an array of depth-area-duration ratios (with the 24-hr, 10-mi^2 (26-km^2) ratio equal to 100 percent, or, 1.0) as shown in table 17.

Table 17.--Depth-area-duration relations to 24 hrs and 400 mi^2 (1,036 km^2) in percent of the 24-hr 10-mi^2 (26 km^2) probable maximum precipitation

	Area mi^2 (km^2)			
Duration (hrs)	10 (26)	100 (259)	200 (518)	400 (1036)
6	.50	.46	.43	.40
9	.63	.58	.55	.51
12	.74	.74	.66	.62
18	.89	.84	.80	.76
24	1.00	.94	.91	.87

3.8.2 Extension of Relations to 72 hours

For the present study, it was necessary to provide PMP estimates for durations between 24 and 72 hours. This required expansion of the previously developed depth-area-duration ratios to provide estimates for the longer durations.

3.8.2.1 Adopted 3- to 1-day Ratio for 10-mi^2 (26-km^2) Rainfall. A first step in determining an appropriate 3- to 1-day ratio was the examination of large observed 1-day rains. The rainiest observing station in southeast Alaska is Little Port Walter. A plot of 36 cases of 72- to 24-hr rainfall ratios for Little Port Walter 1-day rains of 6 in. (152 mm) or more showed that the ratios tend to converge toward 1.60*. Since the selection was made on the basis of maximum 1-day rains, the resulting ratio (i.e., 1.60) should be considered on the low side since the denominator of the ratio was emphasized. That is, a selection of a comparable number of cases based upon maximum 3-day rains would tend to result in a higher ratio.

*The mean ratio for the 36 cases was 1.59.

A second source for developing 72- to 24-hr ratios involved depth-duration summaries of average ratios for statistical return period estimates of 100-yr 1- and 3-day values from Technical Paper No. 47 (Miller, 1963) and Technical Paper No. 52 (Miller, 1965). For a summation of ratios for 100-yr return period rains, Alaska was divided into a maritime zone (southeast Alaska and the south coast), the interior, and intermediate transition zone. For the maritime region, which includes our study area, the average 72- to 24-hr ratio was 1.75.

Earlier PMP estimates made for southeast Alaska provide a third source for estimating 72- to 24-hr ratios. A PMP estimate for southeast Alaska for Takatz Creek (Riedel, 1967) was based upon a detailed study that included computations using a laminar flow orographic model. For this "control" basin the 72- to 24-hr ratio of 1.70 for 10 mi^2 (26 km^2) is appropriate for our region.

3.8.2.2 Extension of Depth-Duration Ratios to Other Area Sizes. Using the 1.70 for our adopted 72- to 24-hour ratio and values from table 17 for durations of less than 24 hrs at an area of 10 mi^2 (26 km^2), a smooth depth-duration curve was constructed. Values for durations of 36, 48, and 60 hrs were interpolated from this curve. An extrapolated depth-area curve for 72 hrs was then constructed to 400 mi^2 (1,036 km^2) paralleling the curve for 24 hrs. Curves for the intermediate durations were then interpolated between these two curves using the previously determined 10-mi^2 values as starting points.

Although these sources are not completely independent, each has examined the data from a different perspective. The ratios obtained from these different approaches vary between 1.65 and 1.75. Figure 30 shows the adopted set of DAD values, with the 24-hr, 10-mi^2 (26-km^2) value equal to 100 percent.

3.8.3 Procedure for Use of Basic Depth-Area-Duration Values

PMP values for a basin are determined and used as follows:

a. First determine the average PMP for 24 hr and 10 mi^2 (26 km^2) by averaging the values read for a basin from figure 27.

b. Read the ratios at the area of basin from figure 30.

c. Multiply values in step a. by ratios obtained in step b. to get accumulative PMP values for the basin area for the appropriate durations.

d. Plot a depth-duration curve from values in step c. and read accumulative depth-duration values for all desired durations.

e. Subtract successive values in step d. to obtain incremental values.